JOURNAL OF THE A·I·E·E·

SEPTEMBER 1930

PUBLISHED MONTHLY BY THE
AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS
33 WEST 39TH ST· NEW YORK CITY

MEETINGS

of the

American Institute of Electrical Engineers

MIDDLE EASTERN DISTRICT MEETING, No. 2, Philadelphia, Pa., October 13-15, 1930

SOUTHERN DISTRICT MEETING, No. 4, Louisville, Kentucky, November 19-22, 1930

ANNUAL WINTER CONVENTION, New York, N. Y., January 26-30, 1931

MEETINGS OF OTHER SOCIETIES

American Electrochemical Society, Hotel Statler, Detroit, Michigan, September 25-27, (C. G. Fink, Columbia University, New York)

National Safety Council, Pittsburgh, September 29-October 4, (W. H. Cameron, North Wacker Drive, Chicago)

National Electric Light Association

Great Lakes Division, French Lick Springs, Ind., Sept. 25-27, 1930, (T. C. Polk, 20 North Wacker Drive, Chicago, Illinois)

New England Division, New Ocean House, Swampscott, Mass., September 29-October 1, 1930. (Miss O. A. Bursiel, 20 Providence Street, Boston)

Rocky Mountain Division, Franciscan Hotel Albuquerque, N. M., October 20-22, (O. H. Weller, Public Service Co. of Colorado, Denver)

American Society of Civil Engineers, Fall Meeting, St. Louis, Mo., October 1-3, (George T. Seabury, Secretary, Engineering Societies Building, 29 West 39th Street, New York)

Illuminating Engineering Society, Hotel John Marshall, Richmond, Va., Oct. 7-10, (E. H. Hobbie, 29 West 39th St., New York)

American Gas Association, Atlantic City, N. J., October 13-17, 1930, (Kurwin R. Boyes, Secretary, 420 Lexington Avenue, New York)

JOURNAL of the A. I. E. E.

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33 West 39th Street, New York

PUBLICATION COMMITTEE
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George R. Metcalfe, *Editor*

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Institute and Related Activities

A REQUEST FOR CHANGE OF ADDRESS must be received at Institute headquarters at least ten days before the date of issue with which it is to take effect. Duplicate copies cannot be sent without charge to replace those issues undelivered through failure to send such advance notice. With your new address, be sure to mention the old one indicating also any changes in business connections.

(The Journal of the A. I. E. E. is indexed in Industrial Arts Index.)

American Institute of Electrical Engineers

—*Some Activities and Services Open to Members*—

Conventions.—The Institute holds three national conventions each year; the Winter Convention in January, the Summer Convention in June, and the Pacific Coast Convention usually in September.

Employment Service.—The employment service is a joint activity administered by the Civil, Mining, Mechanical, and Electrical Engineering societies and is available to the membership of these societies. Branches of this Department are located in Chicago and San Francisco, the main office being located at the societies headquarters in New York. The service is designed to be mutually helpful to engineers seeking employment, and concerns desiring to secure the services of engineers. This department is financed by contributions from the societies maintaining it and from beneficiaries of the service. Further details will be furnished on request to the Managers of the Employment Service at the main or branch offices, addresses of which will be found elsewhere in this issue.

Scope of Papers.—Institute papers should present information which adds definitely to the theoretical or practical knowledge of electrical engineering and may be derived from activities in any of its branches. Acceptable subject matter is as follows: New theories or new treatments of existing theories; Mathematical solution of electrical engineering problems; Researches, fundamental or practical; Design of equipment, and of electrical engineering projects; Engineering and economic investigations; Operation and tests of electrical equipment or systems; Measurements of electrical quantities; Electrical measurement of non-electrical quantities; Applications of electricity to industrial or social purposes; Education; Standardization; Cooperative engineering organizations; Ethical and social aspects of the profession.

Attendance at Conventions.—Taking part in the Institute conventions is one of the most useful and helpful activities which membership in the Institute affords. The advantages offered lie in two distinct channels; technical information and personal contacts. The papers presented are largely upon current problems and new developments, and the educational advantages of hearing and taking part in the discussion of these subjects in an open forum cannot but broaden the vision and augment the general knowledge of those who participate. Equally advantageous is the opportunity which conventions afford to extend professional acquaintances and to gain the inspiration which grows out of intimate contact with the leaders in electrical engineering. These conventions draw an attendance of from 1000 to 2000 people and constitute milestones in the development of the electrical art.

To Members Going Abroad.—Members of the Institute who contemplate visiting foreign countries are reminded that since 1912 the Institute has had reciprocal arrangements with a number of foreign engineering societies for the exchange of visiting member privileges, which entitle members of the Institute while abroad to membership privileges in these societies for a period of three months and members of foreign societies visiting the United States to the privileges of Institute membership for a like period of time, upon presentation of proper credentials. A form of certificate which serves as credentials from the Institute to the foreign societies for the use of Institute members desiring to avail themselves of these exchange privileges may be obtained upon application to Institute headquarters, New York. The members should specify which country or countries they expect to visit, so that the proper number of certificates may be provided, one certificate being addressed to only one society.

The societies with which these reciprocal arrangements have been established and are still in effect are: Institution of Electrical Engineers (Great Britain), Societie Francaise des Electriciens (France), Association Suisse des Electriciens (Switzerland), Associazione Elettrotecnica Italiana (Italy), Koninklijk Instituut van Ingenieurs (Holland), Verband Deutscher Elektrotechniker E. V. (Germany), Norsk Elektroteknisk Forening (Norway), Svenska Teknologforeningen (Sweden), Elektrotechnicky Svaz Ceskoslovensky (Czechslovakia), The Institution of Engineers, Australia (Australia), Denki Gakkwai (Japan), and South African Institute of Electrical Engineers (South Africa).

Library Service.—The Engineering Societies Library is the joint property of the four national societies of Civil, Mining, Mechanical, and Electrical Engineers and comprises one of the most complete technical libraries in existence. Arrangements have been made to place the resources of the library at the disposal of Institute members, wherever located. Books are rented for limited periods, bibliographies prepared on request, copies and translations of articles furnished, etc., at charges which merely cover the cost of the service. The Director of the library will gladly give any information requested as to the scope and cost of any desired service. The library is open from 9 a. m. to 10 p. m. every day except holidays and during July and August, when it closes at 5 p. m.

Annual Reports of Technical Committees

These reports which were submitted at the Summer Convention of the Institute constitute a résumé of the progress in the field of each committee. They are printed in full except for the bibliographies, which here are omitted.

ELECTRICAL COMMUNICATION*

To the Board of Directors:

This Committee supervised the preparation of quite a number of papers during the year, among them being fifteen papers on technical subjects which were finally presented to the membership during the Winter and Summer Conventions. Over two hundred communication papers on various subjects were presented before the A. I. E. E. in the different sections of the country during this period.

The various branches of electrical communication engineering have made considerable progress during the year as is indicated by a summary of the principal developments referred to in the following report:

TELEPHONE SERVICE IMPROVEMENTS

During the year 1929, considerable progress was made in improving telephone service and extending its scope. The growth in the number of telephones in the United States was approximately 900,000, the largest number for any one year, representing an increase of about 4.6 per cent. The total number of telephones by the end of 1929 was approximately 20,230,000. The number of daily toll conversations increased 9.5 per cent to a total of about 3,520,000.

The acceleration in the use of telephone service by the public has been accompanied by increased programs of construction of telephone plant and equipment involving an increase in expenditure of approximately $445,000,000 or 11.8 per cent in investment during the year.

As a result of the efforts of operating and staff organization there has been improvement in local exchange telephone service. The telephone companies have opened schools for the instruction of private branch exchange switchboard operators who are the employees of subscribers. Since about one-fifth of all telephones receive service through private branch exchanges, this plan seems well justified. In addition, the operating companies are supplying an increasing number of experienced operators for private branch exchanges.

Mechanical and electrical troubles have been reduced a measurable extent and the handling of information calls has been improved by means of better equipment and improved methods.

The introduction of improved operating practises and facilities, permitting the use of simplified methods of operation similar to those employed for local business, has substantially speeded up the handling of toll service. More recently, as a further step in realizing improvements in the quality of the toll service as a whole, and particularly between widely separated points, there has been developed a general basic routing plan designed to offer the highest practicable standards of service as regards the speed, accuracy and transmission efficiency in the handling of toll messages. This plan, known as the General Toll Switching Plan, provides essentially for the basic layout and design of the toll plant in a manner which will limit the number of switches required in routing toll calls and provide generally improved transmission standards for toll connections.

TELEPHONE PLANT

The extension of toll cable continued even more rapidly during 1929 than for the previous year. Approximately 3700 miles of loaded inter-city cable were added to the system together with about 1300 miles of short-haul toll cable, making a total of 5000 miles for the year and a total of toll cable both long- and short-haul for the United States of about 20,000 miles. The greater part of this mileage is in the north-eastern section of the country, but extensions are being made rapidly in the south and west. Continuous cable plant now extends from Bath, Maine, to Charlotte, North Carolina, and westward over several routes as far as Iowa City, Iowa. An extensive mileage in operation on the Pacific Coast has been made continuous from San Francisco to Fresno. About 74 per cent of the toll wire mileage is now in cable as compared with 53 per cent five years ago. These cables, which carry about 300 telephone circuits and as many telegraph circuits, for the so-called full-sized cable, are loaded at intervals of about a mile, while repeater stations are placed about 50 miles apart.

Some of these long distance cables have been placed underground while others are suspended aerially. There are many situations where the aerial type of construction satisfactorily meets requirements and it is not so expensive as the use of conduit with manholes at regular intervals. Recently there have been introduced

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Presented at the Summer Convention of the A. I. E. E., Toronto, Ont., Can., June 23-27, 1930. Printed complete herein.

in this country two methods for securing more economically the advantages of the underground cable where the rate of growth does not require the frequent placing of additional cables. In one of these methods a cable, protected by means of impregnated paper, jute, and steel tape covering, is buried in the ground without conduit. In the second method a single fiber conduit is laid and the lead covered cable is drawn into it. In both these new methods manholes are placed only at points where loading coils are to be inserted. This results in the reduction of the number of manholes as compared to previous practise from about eight per loading section to only one.

In the application of these new methods special trench digging and filling machines are employed and under certain conditions a tractor plow has been effective in opening a trench.

Pressure testing of cable with gas to indicate leaks in the sheath is now coming into general use in connection with the installation and maintenance of toll cables.

A special high-speed cable delivery truck for use on private right-of-way has been developed to replace caterpillar type tractors and trailers formerly used for this purpose. Interesting features of this truck are four-wheel drive and two sets of tires for each wheel. One set of tires for the front wheels is smaller than the other and does not come in contact with a hard road surface, thus insuring easy steering in driving on highways. Under the most difficult conditions the speed of the truck is approximately 10 miles per hour compared with about 2 miles per hour for the tractor and trailer. On the road the truck has a speed of about 30 miles per hour.

Telephone Equipment and Circuits

The use of currents of frequencies below the voice range, for calling or ringing, permits economical types of apparatus at the terminals of the circuits but requires means for relaying the signals at each intermediate repeater station. Voice-frequency signaling eliminates this relaying apparatus, and its use on toll circuits has been extended recently by the development of improved equipment for the purpose. This new equipment employs signaling current so small that the interference into neighboring circuits is negligible and provides a degree of selectivity such as practically to eliminate false operation. The new equipment is being applied on the majority of toll circuits having one or more intermediate repeaters with consequent economy in equipment and reduction in maintenance.

The increased demand for toll service has required a corresponding increase in the size of circuit groups between cities and the extension of toll circuits over greater distances, many of these new circuits being in cable. With this increase in the number of toll circuits, improvements in testing arrangements followed, and a new type of test and control board has been developed. This provides for concentrating the toll circuit apparatus before plant attendants, in the same way as at the switchboard, together with more efficient and precise testing facilities for locating faults. Other features of the new arrangements provide for circuit flexibility to care for changes in traffic loads and plant failures and in automatic indication of circuit status for the traffic and plant supervisors.

Dial System Service and Equipment

The growth of dial system service in the United States during 1929 was rapid and is represented by an increase of dial telephones of approximately 850,000 or 24.3 per cent. Approximately 21½ per cent of the total telephones in the United States are now operated on the dial basis.

An interesting development in connection with tandem equipment of the panel type for such cities as New York, Chicago, and Boston is a new call announcer which speaks the number to the manual operators, using the same general principles of sound recording and reproduction by film as are employed for talking motion pictures. A narrow beam of light is passed through a film record of the voice to a photoelectric cell. The machine consists of 14 individual speech channels corresponding to the 10 digits and 4-party letters. These give a constant repetition of each numeral or letter with a silent interval. Connection is made automatically and in succession to the proper speech channels to make up the number wanted, the switching from one channel to the next taking place in the silent interval. The machine is common to an office and will facilitate extension of the tandem method to the more distant manual suburban offices.

Telephone Circuits in Radio Broadcasting

The use of telephone circuits for connecting long chains of radio broadcasting stations continued to increase during the past year. On March 4, 1929, during the inauguration of President Hoover, more than 30,000 miles of telephone program circuits carried the ceremonies to 118 broadcasting stations in all parts of the country, making the occasion the largest chain broadcast that has ever occurred. The exercises were also heard by many listeners in different countries through short-wave transmission.

Carrier Telephone Systems

The rapid extension of carrier telephone facilities throughout the United States continued during 1929. The increase in number of channel miles in service was approximately 135,000, or 57 per cent.

Transoceanic Telephony

The development of international telephony during the past two or three years has proceeded with such astounding rapidity that about 87 per cent of the world's telephones are now interconnected by the aid of transoceanic radio telephony.

During the year a further rapid development occurred in the use made of and in the facilities provided for transatlantic telephone service. The previously existing facilities of one long-wave circuit and one short-wave

circuit have been supplemented by two additional short-wave circuits, making a group of four circuits functioning to interconnect the continental wire telephone networks of North America and Europe.

At the Winter Convention there was presented a group of four papers under the general subject of Transoceanic Telephone Service which discussed, in some detail, these new short-wave facilities and their relation to the older facilities.

Two important extensions of international commercial telephone service during the year were the opening of service between Madrid and Buenos Aires on October 12, 1929, and between New York and Buenos Aires on April 3, 1930. These additional short-wave radio telephone systems have made possible the connection of the telephone networks of Europe and of North America with those of Argentina, Uruguay, and Chile and should be an important factor in influencing commercial and political relations between the continents.

Ship-to-Shore Telephone Service

Experiments of ship-to-shore radio telephony, which have been made from time to time since 1920, resulted in commercial service from the United States to the *S. S. Leviathan* on December 8, 1929, and from Great Britain to the *S. S. Majestic* in the middle of February, 1930. Experiments have also been made with other ships and it is expected that commercial service will be extended as fast as the necessary ship installations can be made.

This ship-to-shore service is being given in the short-wave range and requires the provision of a number of wavelengths for covering the different distances and different conditions due to time of day.

The coastal transmitting and receiving stations in the United States are located on the New Jersey coast, about 60 miles south of New York, the transmitter at Ocean Gate and the receiver at Forked River. Pending the completion of the transmitting station, a station located at Deal Beach, New Jersey, is being employed. These stations are connected with New York by wire line and the technical control of the circuit, as well as the traffic operation, takes place in the long-distance telephone building in New York.

Telephone Communication with Airplanes

The Bell Telephone Laboratories has for some time been conducting experimental and development work on the difficult problem of two-way telephone communication between airplanes and the ground. In this work two airplanes are employed which are equipped with apparatus designed to make accurate measurements and tests while the plane is in the air. Tests have shown that satisfactory two-way telephony is possible between airplanes and practically any telephone connected with the United States. In several of the tests commercially satisfactory communication was maintained between an airplane here and telephone stations in Europe. This involved radio transmission from the airplane to the Bell Telephone wire system in the United States, the transatlantic radio and the regular telephone wire system in Europe.

Largely as a result of this work two-way radio telephony for plane-to-ground communication has advanced to the point where commercial apparatus is now becoming available and regular transport planes of several lines will soon be equipped with it. This should add greatly to the safety and reliability of air transportation. In addition to the pilot receiving weather and landing conditions reports and other data, he can in return keep the dispatcher informed of his position and of the weather conditions along the airway.

International Technical Conference on Radio

The fact that in radio the nations of the world share a common transmitting medium makes it important that there be international understanding on the technical standards which are to be met in order to minimize interference. There occurred at the Hague last September the first meeting of a newly organized international technical committee, known as the International Technical Consulting Committee on Radio Communication, or, more briefly, the CCIR. The meeting was attended by some two hundred government and company technical experts from the principal nations of the world.

The findings of the committee are purely advisory, but will undoubtedly have weight throughout the world, since they represent the best world opinion obtainable upon the subject. Without going into the details, it is interesting to note that constructive proposals were adopted upon the following subjects: (1) methods for comparing the frequency standards of the different nations; (2) accuracy with which stations should be expected to hold to their frequencies; (3) the frequency intervals at which stations should be assigned.

Radio Telegraph

Commercial marine radio service was established at New York City and Sayville, L. I., with ships at sea on May 15, employing modern short-wave service as well as the usual intermediate and long-wave lengths. An additional marine station has just been completed near West Palm Beach, Florida, and was opened to general public service on February 28.

Commercial transcontinental radio telegraph service connecting the Atlantic and the Pacific Coasts was inaugurated on November 15. This service not only joins the ship-to-shore services centering at San Francisco and New York City, but also extends the Pacific Coast point-to-point and Honolulu radio circuits to New York, connecting with radio telegraph services already established, to South America and those contemplated.

An additional commercial transoceanic radio telegraph service was established between New York and Lima, Peru, on December 11. This service is conducted jointly by the Mackay Radio and Telegraph Company, operating at Sayville, L. I., and the All American Cables, Inc., operating at Lima, Peru.

Carrier Telegraph Systems

The past year has witnessed a rapid growth in the application of carrier telegraph in this country. Approximately 200,000 channel miles of carrier telegraph have been placed in service, representing an increase of about 44 per cent for the year.

Progress has been made during the year in increasing the number of carrier telegraph channels which it is possible to obtain from both open-wire and cable circuits. Furthermore, carrier telegraph and carrier telephone systems have been combined in a way to provide considerable flexibility in obtaining different ratios in the number of telephone and telegraph channels which it is possible to obtain from a given group of line circuits.

For open-wire lines suitable for the transmission of carrier frequencies, trials are under way which indicate that the number of carrier telegraph channels which it is possible to obtain from one pair of wires may be increased from 10 to a maximum of 36. One pair of wires may also provide a combination of one carrier telephone channel and 24 carrier telegraph channels, or two carrier telephone channels and 12 carrier telegraph channels.

There was a continued increase in the application of carrier current telephony and telegraphy for the efficient use of existing plants in America and Europe, especially in Spain, France, and Italy, Australia and other localities. In Australia and New Zealand notable advances have been made in carrier current communication where the great distances are peculiarly adapted to this type of operation.

Cable Telegraphy

The Western Union Telegraph Company successfully completed duplexing experiments at Bay Roberts, Newfoundland, on the Bay Roberts-Horta, and on the Azores duplex loaded cable, the development and laying of which were noted in the 1929 report. A duplex balance was obtained satisfactory for operation at 1400 letters per minute. This is somewhat higher than the speed for which the cable was designed and is several times as high as the duplex speed of any previous long cable. An ultimate speed greater than 1400 letters in each direction is possible. The artificial line for balancing the cable, as well as the cable itself, is of unusual design, in that in addition to matching the inductive loading of the cable, it was also necessary to take into account various factors which are neglected in balancing for low speed operation.

A severe earthquake was registered on most of the seismographs of the world on the afternoon of Monday, November 18, 1929, which was the cause of ten submarine telegraph cables off the east coast of North America being severed. Nearly all were broken at more than one point. The location of the epicenter, as determined from earthquake records, was given by the Dominion Observatory, Ottawa, as 44° 30′ North Latitude 57° 15′ West Longitude, and the time 3.32 : 8 p. m. Eastern Standard Time. Some of the breaks did not occur at the time of the earthquake, but several hours later which would seem to indicate that there were further tremors. No less than eight cable repair ships were immediately dispatched to make the necessary repairs. Fortunately the cable companies have duplicate cables and alternate routes so international communications were not affected to any great extent.

Airways Communications

The San Francisco-Los Angeles weather reporting network established last year on an experimental basis through cooperation of the Weather Bureau, the Daniel Guggenheim Fund for the Promotion of Aeronautics, and the Pacific Telephone and Telegraph Company, has since been taken over by the Airway Division of the Department of Commerce. Through the cooperation of the Department of Commerce and the telephone companies, similar systems have been established along the New York-Chicago airway. An even more extensive system has been put in operation for the Transcontinental Air-Transport along its air-rail route across the continent. In these systems, telephone typewriter circuits connect the meteorological collection and distribution centers. This information is relayed to planes in the air by means of radio telephone apparatus.

Printing Telegraphy

During the past year, over one hundred of the concentration equipments for printing telegraph circuits mentioned in the last year's report have been scheduled for installation and at least ten are already in operation. The operating economies expected from the use of the concentrators have been more than realized.

The increase in the number of telephone typewriters used in the Bell System was very marked during the past year. Approximately 7000 machines were added, representing a growth of about 140 per cent during the year. The number of circuit miles used in telephone typewriter service has increased by approximately 280,000 or 64 per cent during the year. The difference in the rate of growth between telephone typewriters and circuit miles is due to the rapid growth of the telephone typewriter service in local areas, where the connecting circuits average only about five miles each.

Recently, experimental telephone typewriter exchange service was installed in telephone company offices in New York, Boston, Chicago, and some adjacent cities, and the practicability of this type of commercial service was demonstrated. Telephone typewriter instruments are in a large measure as adaptable as telephone instruments and can be interconnected through special switchboards in much the same manner. A subscriber, wishing to be connected to another one in the same city or in a distant city, communicates with a switchboard operator using his telephone typewriter, and the operator makes the connection to and signals the called subscriber. After the called subscriber answers, messages are passed between the subscriber

in much the same manner as over a telephone system, except that a written record is obtained at both stations. Arrangements can also be made so that one station can be connected to a number of others and broadcast information to them.

In the private branch exchange field, a number of different types of installations of telephone typewriter switching systems were made. Several automobile manufacturing companies, for example, have found these systems very efficient for production control in their factories and warehouses. Another example is the installation used by the credit bureau of one of our large cities.

Automatic Stock Quotation Boards

The past year has seen the introduction on a fairly wide commercial basis of automatic stock quotation boards in brokers' offices for electrically recording market prices. Some of these boards are controlled from a central point over telegraph circuits; others are operated locally from keyboards installed in each broker's office. One type of board is designed to display the last dozen or more sales so as to indicate the trend of the market.

On May 21, 1929, the first Teleregister type of automatic stock quotation board was placed in service in a broker's office in New York City. Since that time the demand for this service has been so great that within nine months approximately 20 per cent of the board rooms in New York City were receiving automatic service of some form.

With this particular type of equipment, all boards in a city or in a zone which may have a radius of several hundred miles are operated from a central transmitting station.

Mechanical Conveyers for Telegrams

A new type of conveyer wherein the telegram is carried on its edge on a moving belt in a narrow trough has been developed by the Western Union Telegraph Company for collecting telegrams from operating positions in large offices. This conveyer is called a "V Belt Conveyer" and takes its name from the shape of the trough in which the messages are carried. The belt runs along the back edge of the operating table and is readily accessible to the operator for depositing received telegrams thereon; a series of V belts carry the telegrams to a central point where the messages are routed to outgoing wires.

Municipal and Protective Signaling

There has been considerable extension of electrical traffic signals. The newer devices show a decided shift toward the "New Jersey" cycle, green, amber, red, green.

In congested districts there has been a considerable increase in progressive signals. With these a vehicle starting at one end of a street protected with a green light may travel through to the end without being delayed by a red light provided speed is kept within predetermined limits. There has also been a considerable increase in signals controlled by the vehicle. These are set to show green normally on the more traveled route and are reversed by vehicles running over a switch or magnet in the street. These have not yet been made satisfactory for congested districts since they do not make suitable provision for pedestrians, but improvements are being made to overcome this and other disadvantages.

The most important change in municipal fire alarm systems during the past year is a tendency to adopt improved current supply arrangements. One such type of arrangement is the single battery with trickle charger using copper oxide rectifiers or similar charging devices in place of duplicate batteries charged alternately by motor generators. Another type of improvement is the sealed type storage cell which is rapidly replacing the loose top cell. Similar improvements are being adopted for police signal systems.

The use of telephone typewriter systems by police organizations has gained headway. There are more than ten such systems now in service, including installations for the New York City police organization and the Pennsylvania State Police, each containing as many as 100 telephone typewriter stations.

Television

During the year there has been extensive progress in fundamental development.

This has included work on the application of television both to wire and radio systems. Television in colors was first demonstrated last June over a short wire circuit. This employs a new type of photo-electric cell responsive to all the colors of the visible spectrum, an improvement on the former type, which was sensitive only at the blue-green end. Special argon tubes combined with neon tubes previously used, together with color filters and new arrangements of apparatus, are employed. Moving as well as stationary objects can be clearly seen in their natural colors.

Sound Pictures

The growth in the use of sound picture systems in theaters continued and sound projection equipment is now universally applied in important motion picture theaters In the recording field improvements have been made in sound quality as the result of improved pickup devices, by refinements of electrical circuits, by better optical systems in the case of film recording, and refinements in photographic processes for handling films. Rerecording has become quite general in studio practise and special rerecording equipment has been developed. Both disk and film methods of sound recording continue in favor with the producers.

In projection, improvements in sound quality have resulted from improved optical systems and pick-up devices, and improved loudspeakers and driving mechanisms generally. Acoustic treatment of theaters to

secure better conditions for sound projection in theaters are found to be substantially different from those for direct audition in assembly halls.

A paper describing the technique and apparatus of sound picture recording and reproduction entitled *The Electrical Engineering of Sound Picture Systems* was presented at the Pacific Coast convention, at Santa Monica, California, September, 1929, by Messrs. K. F. Morgan and T. E. Shea.[1]

Foreign Telephone and Telegraph Matters of Interest

While the Communication Committee has made no complete record of communication developments in other countries, the following items which have been brought to the attention of the Committee are believed to be of interest:

In Europe, in 1929, 25 new international long-distance circuits were put into service between places not previously connected with each other. In some cases, there were services between two cities, in other cases between some principal city in one country and numerous cities in another country, and in other cases, numerous cities in two countries. This, the most rapid expansion of international long distance telephony which has ever taken place in Europe in one year, was made possible by the underground cables which have been laid within the last four years, during which period the number of important European cities connected internationally increased from 17 in 1925 to 76 up to the middle of 1929. The increase in service has been accompanied by a corresponding improvement in quality of transmission, and in density of traffic.

The Anglo-Polish service was extended into Poland to Cracow, Lodz, Poznan, and other towns. The Lodz exchange was connected by long distance with the Swiss telephone system. Nine additional departments of France were given telephone service with Switzerland so that the whole of that country, with the exception of Corsica, is now connected with the Swiss network. In addition, telephone communication between Copenhagen, Genoa, Milan, and Turin has been established via Switzerland.

Telephone service between Great Britain and Finland, Paris and Finland, Rome and London, Switzerland and Italy, Hungary and Denmark, and Hungary and Poland is now available. Service between Stockholm and Reval, Esthonia, via Helsingfors, Finland, has also been established.

In October, 1929, telephone service was opened between two of the Canary Islands (Gran Canaria and Teneriffe) over a submarine cable nearly 40 nautical miles in length. This is a single-core, non-loaded cable with a copper tape return and is designed for the ultimate operation of six two-way carrier telephone channels in addition to the voice frequency channel and a direct-current telegraph circuit. The cable is in some places nearly 2 miles below the surface of the ocean.

A 20-nautical-mile telephone cable was laid between Algeciras, Spain, and Ceuta, Morocoo, to supplement the cable placed between these points in 1924. This cable is designed for one telegraph circuit, one voice frequency telephone and six carrier telephone channels.

A 12-quad non-loaded cable, 37 nautical miles in length, was placed between Buenos Aires, Argentina, and Colonia, Uruguay. This cable is operated on a 4-wire basis in connection with 2-wire open-wire circuits from Colonia to Montevideo. The pairs have been equalized to 5000 cycles which has made it possible to secure very satisfactory results in broadcasting from Montevideo opera and other programs given at Buenos Aires.

In September, the new underground Paris-Lyon-Marseilles telephone cable was opened for service. It is 800 km. long and contains 130 circuits. In October, the new Italian underground cable linking Naples with Florence was inaugurated. The year also saw the underground telephone cable between Vienna and Graz extended to the Jugoslavian frontier, and the new East Prussian submarine cable laid between Leba and Pillau.

The Czechoslovakian Government during the year placed an order for a 120-kw. broadcasting station at Prague. So far as is known, this is the largest station which has been planned up to the present time in Europe.

1. A. I. E. E, Trans., Vol. 49, January 1930, pp. 105-116.

ELECTRICAL TRANSPORTATION*

To the Board of Directors:

In accordance with instructions, your Committee submits a brief review of the recent developments of importance in the application of electricity to transportation.

Steam Railroad Electrification

Pennsylvania Railroad. The Pennsylvania Railroad is actively engaged in the construction of three sections of its electrification program. These sections are from Philadelphia to Trenton, N. J., Philadelphia to Norristown, and New Brunswick to Jersey City and Sunnyside Yard. This construction work involves 88 route miles and 370 track miles. Until the section between Tren-

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ton and New Brunswick is completed, only multiple unit passenger service will be operated electrically in addition to the present electrified service. This electrification utilizes power distribution at 11,000 volts, 25 cycles, single phase.

Delaware, Lackawanna & Western Railroad. This project, comprising 67.9 route miles with 160 track miles, is progressing. Power contracts have been executed with the Public Service Electric & Gas Company, the Jersey Central Power & Light Company, and the New Jersey Power & Light Company. One hundred and forty-one multiple unit motor cars, each equipped with four motors, have been ordered. The coaches now used in steam operation will be equipped for use as trailers. Each motor car will be permanently coupled to a trailer to form a unit. The substation converting apparatus is to consist entirely of mercury arc rectifiers, which are all now in process of installation. It is expected that the construction will be substantially completed by the end of 1930. This will be the first extensive installation in this country of 3000-volt d-c. power distribution applied to motor car equipment.

Reading Railroad. The Reading suburban electrification in the vicinity of Philadelphia is progressing according to schedule, although it has been held up somewhat by grade crossing elimination. The initial installation will consist of about 50 route miles and 110 track miles, and the equipment will be multiple unit cars, orders for which have been placed. It has been stated that a second step is contemplated upon completion of the first, between Langhorn and Bound Brook and New York and Lansdale to Bethlehem and along the Schuylkill Valley to Reading. Contract has been made for purchase of power with the Philadelphia Electric Company. This electrification is on the basis of 11,000-volt, single-phase, 25-cycle power distribution.

Cleveland Union Terminals Company. The construction of the two substations and six circuit breaker houses or tie stations required for this electrification project, has been completed. Twenty-two 204-ton, 3000-hp. locomotives have been delivered, and power is being supplied to the catenary system west of the terminal for the purpose of training locomotive crews. All construction work will be completed this year and the operation of trains by electric power will begin before the end of the year. The conversion of power will be by means of motor-generator apparatus and the trolley voltage will be 3000 volts direct current. Contract has been executed for purchase of power with the Cleveland Electric Illuminating Company.

New York Central Railroad—West Side, New York City. In connection with the electrification of the freight service on the west side of New York City, south of Sputen Duyvil, three new substations are being constructed. They will be automatic or operated by means of supervisory control. Forty-two road freight locomotives of a capacity of 2500 hp. each have been ordered for operation between Croton and the 72nd Street yard. They will weigh approximately 275,000 pounds and will be operated from 660-volt d.-c. third rail. For switching in the yards, and operation of the freight trains south of 60th Street, thirty-five combination oil-electric-battery locomotives have been ordered. The Diesel engines on these locomotives will have a capacity of 300 hp. and the battery will have a capacity of 650 ampere hours at the 6-hour rate, at an average voltage of 464 volts. The approximate weight of these locomotives will be 257,000 pounds.

Great Northern Railroad. It has been necessary to add new equipment on account of increased demand for service, and four additional motor-generator type locomotives, duplicates of those now handling the passenger service, are under construction. This electrification is on the basis of 11,000-volt, 25-cycle, single-phase power distribution.

New York, New Haven & Hartford Railroad. Authority has been received for purchase of ten new electric locomotives and thirty-three multiple-unit cars in addition to nine multiple-unit cars which have been received during the year. This electrification is 11,000 volt, 25 cycle, single phase.

Illinois Central Railroad. During the past year, freight tracks and yards from Monroe Street to 39th Street, Chicago, having a total mileage of 21.2 track miles, have been electrified as an integral part of the present electrification, which utilizes 1500-volt d-c. distribution. Freight service in these yards will be handled by four 100-ton straight electric locomotives having a one-hour rating of 1460 hp. Switching service on non-wired tracks north of this point will be handled by six 600-hp. oil-electric locomotives, this diversity of motive power being made necessary by the unfeasibility of wiring certain yard tracks north of Randolph Street. This project will enable the handling electrically of all freight service north of Roosevelt Road (with the exception of manifest trains) to be done with motive power other than steam, as is called for by city ordinance.

Substations for Electrified Railroads

It is of interest to note that of the two above-mentioned 3000-volt d.-c. traction installations, one is on the basis of mercury arc rectifiers and the other of motor-generators. The substation design characteristics vary accordingly.

Diesel-Electric Locomotives

Four combination oil-electric-battery locomotives, known as "three-power" units, have been ordered by the Michigan Central Railroad for use in Chicago. The New York Central Railroad has ordered two and the Chicago, Rock Island & Pacific Railway one, of

the same type, for use at the La Salle Street terminal, Chicago. Thirty-five oil-electric-battery locomotives have been ordered by the New York Central Railroad in connection with the west side electrification in New York City, as above mentioned.

The Delaware, Lackawanna & Western Railroad has ordered two three-power locomotives equipped to receive power from 3000-volt, d-c. trolley. These engines in general resemble those of the New York Central Railroad.

The Illinois Central Railroad, as above stated, has in operation six 600-hp. Diesel-Electric locomotives.

The Erie Railroad has purchased one 800-hp. Diesel-electric locomotive.

Perhaps the outstanding Diesel-electric locomotive of the year is the "No. 9000" of the Canadian National Railways. The two engines of this locomotive have a total rated capacity of 2660 hp. at 800 rev. per min.

Rail Cars

There has been a steady increase in the demand for heavier and more powerful rail car power plants. In 1927, eight cars of over 500 hp. were produced; in 1928, fifteen; and in 1929, thirty-seven cars which weigh about 180,000 pounds. Designs have been completed for two eight-cylinder gas engines of over 500 hp. In this connection, it is of interest to note that five steam rail cars of 400-500 hp. have been ordered.

Marine Transportation

At the close of 1929 there had been completed six turbo-electric driven ships aggregating 56,000 tons, using motors totaling more than 71,000 shaft-hp. capacity. Electric propulsion has been applied for the first time to railroad car ferries, large pleasure yachts, etc. A number of Diesel-Electric craft have been produced.

Aviation

The developments in aviation during the past year include the "altimeter," indicating the distance above the surface of the ground; the magneto compass, virtually a d-c. generator using the horizontal component of the earth's magnetic field as its field; the electric-gasoline engine temperature indicator; and an oil immersion heater for warming oil before starting motor-generators and dynamotors. Power plants of extreme lightness for radio purposes have been developed to take the place of wind-operated generators.

Car Retarders

Retarder installations, both electric and pneumatic, for gravity freight classification yards, have been continued during the past year. One of the advances which has been made is in the use of track circuits and cab signals for the hump yard locomotives. A retarder scheme utilizing a magnetic braking circuit has been tried abroad with considerable promise of success. This will eliminate all mechanical contact with the car wheels.

Signaling

An extension of railroad signaling of importance has been made in centralized remote control of switches and signals, to enable the despatcher to control trains directly (without train orders) by manipulating switches and signals from his office.

Communication on Railroads

Carrier current telegraph circuits have been extended during the past year on railroads. Further tests of communication with moving trains have been made with success, although tests of radio communication between front and rear of long trains have been discontinued under orders from the Federal Radio Commission.

Automatic Train Control

Little additional installation in the field of automatic train control has been indicated during the past year. Two systems, one the so-called "Coder Type" with continuous cab signal indication, and the other the "Intermittent or "Track Induction Type," which merely requires acknowledgment from the engineman when passing a track inductor, are the most common types of installation. Some railroads are installing cab signals over considerable mileage without the train control features.

Street Railways

There has been a great deal of activity in this field during the last two or three years, especially in developing high speed motors with either worm or double reduction gear drive, wherein the motor is entirely spring supported.

The tendency is towards the use of motors of larger capacity than formerly, with lighter cars and very much higher rates of acceleration. In order to secure these higher rates of acceleration with reasonable comfort to the passengers, it has been necessary to develop new control systems with many more steps than in the old hand controllers. The tendency is toward the use of automatic multiple contact control, and a variable automatic control has been developed which may be either foot or hand operated. The rate of acceleration thus depends simply on the pressure of the foot on the pedal.

General

Attention is called to the development of various types of apparatus which apply to transportation as well as to other forms of electric utilization, as described in the appropriate committee reports; such as turbines and other power plant facilities, circuit breakers, lightning arresters, high tension cable, sub-stations, hydro-electric facilities, etc. Attention is especially called to quick-acting circuit breakers, both oil and air, which are especially applicable to railroad work.

ELECTROPHYSICS*

To the Board of Directors:

Progress in the application of results in the domain of physics has been so rapid of late that there is a temptation to make the general statement that the pure physics of one quarter century becomes the engineering of the next. This, of course, would not be true in all domains of physics, but it is more or less valid in those with which the electrical engineer is most closely connected. The mounting number of uses for devices and phenomena discovered some years ago, for example the vacuum tube, photo-electricity, and the piezoelectric vibrations of crystals, is an apt illustration of the transfer from abstract interest to practical utility. It is, then, quite to the point for the electrical engineer, in forecasting and preparing for the developments of the future, to look to the electrophysics of the present day.

The physicist is continuously acquiring increasing clarity of view in connection with principles already to some extent applied. A better understanding of the present viewpoints with regard to these principles may also be of value to the engineer in further applications.

Keeping these two ideas in view, the present report does not confine itself to applied physics. In fact, the material in the first portion of the report, giving a general idea of the developments along the forefront of theoretical and experimental physics, may not find application for a long time to come (although this might also have been said of the advance line of physics many times previously, and belied by subsequent events). Following this general survey, the progress in particular topics of more immediate practical consequence, is summarized. The subjects thus discussed are: dielectrics, magnetism and magnetic materials, the conduction of electricity in solids, photoelectricity, thermionics, the cold discharge, vacuum tubes, gas discharges, the propagation of electric waves, and magnetic and electrostatic fields.

THE "FIRST LINE" OF PHYSICS

Spectacular advances in the various fields of electrophysics have been few during the past year, as they are in any year, but a great deal of serious, accurate, and quantitative work has been recorded in almost every subdivision.

The wave-like qualities of negative electricity were established beyond all reasonable doubt, more than two years ago; but though the recent demonstrations of electron-diffraction by crystals and ruled gratings can scarcely be said to have strengthened a case which was already unassailable, some of the photographs of diffraction-rings and diffraction-fringes published during the past year are so beautiful that they merit special mention (G. P. Thomson, Rupp, Eisenhut, Debye). A beginning has already been made in turning them to practical use in the study of thin films (G. P. Thomson, *et al*). Diffraction of electrons by liquids has been proved experimentally (Debye). The wave-like qualities of positive electricity have been demonstrated (Dempster), though as yet the evidence falls far short, in beauty and in clarity, of that available for negative electricity—a circumstance not to be wondered at, considering the difficulties of the experiments. Finally, the corresponding proof has been achieved for neutral matter (helium and molecular hydrogen, by Stern; atomic hydrogen, by T. H. Johnson). More and more it becomes evident that wherever there are particles, there are waves also; particles are guided by waves, waves are the carriers of particles.

The classical theory of electric conduction in metals, the theory, that is to say, that a metal contains an electron-gas, prevented from escaping by a potential-drop at the surface, was revived some three years ago with a modification, to wit, the substitution of the Fermi distribution-law for the Maxwell distribution-law as applied to the corpuscles of the electron-gas. Later it was modified in another way: by introducing, from wave-mechanics, the idea that the electron-gas can leak out gradually across the potential-drop even though this is so high that no electron within the metal has enough kinetic energy to surmount it. The combination of these two new ideas is being tested in work on the cold discharge, and on the refraction which a beam of electrons undergoes on entering a metal; they supply also a new incentive for accurate work on the photoelectric and the thermionic effect. Unfortunately, it appears that the mathematical complexities which are encountered in attempting to bring the theory closer to the experiments are very serious. Moreover, in the recent work in thermionics and photoelectrics, it is found that the influence of surface-conditions, films of foreign substances only one molecule deep, for instance, or indeed even scantier than would result from a complete covering of the surface by a monomolecular layer, is predominant. While such influences might be explained in part by invoking the second of the new ideas aforesaid, they have apparently nothing to do with the first. It is only too obvious that in these fields very much remains to be understood.

In the study of discharge through gases, where the wave-like qualities of electricity play little or no part, the developments of the last year have mostly been

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continuations of prior work. Since recent refinements in technique make it possible to observe what goes on during intervals of the order of a hundred-millionth of a second, some interesting work on the electric spark is being published. It has been proved that the spark bursts forth so quickly, that rearrangements of spac-charge rather than drifting of ions must be accountable for its onset. The extensive work, both experimental and theoretical, of Compton and Langmuir and the latter's associates, upon the "plasma" or glowing gas of the arc-discharge, is being summarized and developed by the two in articles in the *Review of Modern Physics*, the first of which has just appeared (April, 1930). Several valuable papers on the interception of electrons by atoms, the probability of ionization of atoms by electrons, and cognate subjects have appeared.

Dielectrics

The report of the Committee on Electrical Insulation, Division of Engineering and Industrial Research of the National Research Council, dated July, 1929, shows that there has recently been much activity in this field. Under the auspices of this committee, a symposium on dielectrics was held in connection with the general meeting of the American Physical Society in Washington, in July, 1929. They have also prepared a comprehensive program of research for physicists, chemists, and engineers, stressing the importance of fundamental work in solving the present difficulties due to dielectric absorption, dielectric loss, and conductivity. The situation has been summarized by Professor Whitehead, chairman of the committee (A. I. E. E. Jl., **48**, 27, 1929).

Dielectric breakdown has been discussed in many papers. Halbach (*Arch. f. Elekt.* **21**, 535, 1929) has tested various solids and differentiates between two types, the so-called electric breakdown and breakdown by heat. Moon and Norcross (*Jl. Frank. Inst.* **208**, 705, 1929) have discovered and investigated a third type of breakdown. Inge and Walther (*Arch. f. Elekt.* **22**, 410, 1929 and **23**, 279, 1930) have extended their investigations on breakdown to liquids, and considered the effects of time, of application of voltage, and of the homogeneity of the field on both solid and liquid materials. Jost (*Arch. f. Elekt.* **23**, 305, 1930) has also considered the effect of time on the strength of various solids. Smurow (*Arch. f. Elekt.* **22**, 31, 1929) determined the breakdown field for sulfur in solid, liquid, and gaseous form. A general review of the breakdown of liquid insulators has been published by Gyemant (*Phys. Zeit.* **30**, 33, 1929).

In several papers (*e.g., Zeit. f. Phys.* **56**, 446, 1929 and *Zeit. f. Tech. Phys.* **11**, 81, 1930) Böning has given experimental support to the idea that dielectric breakdown in solids of colloidal origin is affected by ions adsorbed on the inner surfaces of channels. A similar but more elaborate theory has recently been put forward by Murphy and Lowry (*Jl. Phys. Chem.* **34**, 598, 1930) to explain absorption and loss in such materials. This was based in part on previous work on textiles with various electrolyte and moisture contents, the electrical properties of which have been determined by Murphy, Williams, and Walker (*e. g., Jl. Phys. Chem.* **33**, 509, 1929, and A. I. E. E. Trans. **48**, 568, 1929). The effect of moisture in air condensers has been investigated by Lemmon and Kouwenhoven (A. I. E. E. Trans., Vol. 49, July 1930).

Ionization in paper-insulated cables has been studied further by Dawes and Humphries (A. I. E. E. Trans. **49**, 766, 1930) and also by Brown (*Jl. I. E. E.* **67**, 968, 1929). Whitehead and Marvin (A. I. E. E. Trans. **49**, 647, 1930) have found that in a high grade paper-insulated condenser the loss can be fully accounted for by dielectric absorption. Benedict (A. I. E. E. Trans. **49**, 739, 1930) has similarly calculated the power loss from the d-c. characteristics, and investigated the effect of frequency on the charging current and energy loss in various condensers. Owen (*Phys. Rev.* **34**, 1035, 1929) determined calorimetrically the heat loss in a fiber condenser at radio frequencies and found that it is proportional to the voltage and the square of the frequency. The absorption or damping of radio wave-trains in dielectrics has been discussed by Kreutzer (*Zeit. f. Phys.* **60**, 825, 1930).

The power losses in glass have been measured by McDowell and Begeman (*Phys. Rev.* **33**, 55, 1929) as a function of temperature and frequency. The variation of the dielectric constant and power factor of rosin and castor oil with temperature and frequency was found to be qualitatively in accordance with the Debye theory by Kitchin and Müller (*Phys. Rev.* **32**, 979, 1929 and Jl. A. I. E. E. **48**, 281, 1929). Goldhammer and Sack (*Phys. Zeit.* **31**, 224, 1930) studied the anomalous dispersion in dilute solutions where the Debye theory is more nearly applicable, and found results in agreement with the theory. The law of superposition in hard rubber has been confirmed by Race and Campbell (*Phys. Rev.* **34**, 1031, 1929). Electric polarization was observed by Güllner (*Arch. f. Elekt.* **22**, 141, 1929) in gypsum but not in mica nor in any glasses, indicating that the mechanism of the process is different in different substances.

Various experimenters have measured conduction currents as dependent on voltage, time and temperature. A review of previous work in relation to the theories of conduction and diffusion in solid dielectrics, has been made by Jander (*Zeit. f. angew. Chem.* **42**, 462, 1929). Experiments on quartz and rock salt have been made by Goldhammer (*Zeit. f. Phys.* **57**, 173, 1929), on rock salt and gypsum by Salessky (*Zeit. f. Phys.* **52**, 695, 1928), on an artificial resin by Suckow (*Arch. f. Elekt.* **22**, 104, 1929), and on oil by Whitehead and Marvin (A. I. E. E. Trans. **49**, 647, 1930) and by Nikuradse (*Arch. f. Elekt.* **22**, 283, 1929). Nasledov

and Sharavskii (*Ann. d. Phys.* **3**, 63, 1929) have observed the ionizing effect of X-rays by measuring the conduction current in ceresin.

Some of the most fundamental work during recent years is reported in the book "The Physics of Crystals"[1] by A. Joffe.

As in many years past, much of the work in molecular structure as deduced from measurements of dielectric constants, centers around the Debye theory. An excellent review of this subject is given by Debye himself in his recent book "Polar Molecules"[2] to which reference should be made for the fundamentals as well as for the interpretation of the results obtained before 1929. More recent reviews, with special reference to the results for aliphatic compounds and for inorganic and aromatic compounds are those by Smyth (*Chem. Rev.* **6**, 549, 1929) and by Williams (*Chem. Rev.* **6**, 589, 1929), respectively. All of the phases of the subject are treated in papers in the *Leipziger Vortrage*[3] edited by Debye.

Values of electric moments, on which to base atomic and molecular models, are perhaps best determined by studying the effect of temperature on the dielectric constants of gases. Under these conditions the molecules are least affected by neighboring molecules; and it is possible also to separate the moment produced by the distortion of the molecule by the field, from the permanent moment characteristic of the molecule when no disturbing field is present, the latter being the more desirable datum. This method, based on the relation derived by Debye in 1912, has been applied by Sänger and Steiger (*Helv. Phys. Acta* **2**, 130, 1929 and **2**, 411, 1929), by Zahn (*Phys. Rev.* **35**, 848, 1930), and by Schwingel and Williams (*Phys. Rev.* **35**, 855, 1930), to a large number of organic and inorganic compounds. Interesting among these are N_2O, CO_2, CS_2, and SO_2 which have zero moments, indicating that the three atoms in each molecule have a symmetrical linear arrangement. Measurements of the Kerr effect and the scattering of light have been used to determine electric moments by Wolf (*Zeit. f. Phys. Chem.* **3B**, 128, 1929), by Stuart, Briegleb, and Wolf (*Zeit. f. Phys. Chem.* **6B**, 163, 1929), and by Stuart (*Zeit. f. Phys.* **55**, 358, 1929 and **59**, 13, 1929). This work is based on that of Raman and Krishnan (*Phil. Mag.* **3**, 713, 1927).

The dielectric constants and refractive indices of many binary liquid mixtures have been studied by Smyth and his co-workers, and by Williams and his co-workers. These data permit a determination of the electric moment by a third method, using Debye's theory.

There have been many more determinations of the electric moments of various compounds and groups of compounds, and discussions of the structures based on these determinations. For these papers the reader is referred to *Science Abstracts*.

1. McGraw-Hill, 1928.
2. Chemical Catalog, 1929.
3. S. Hirzel, Leipzig, 1929.

Magnetism and Magnetic Materials

The fundamental nature of ferromagnetism has been discussed in many papers during the year. Slater (*Phys. Rev.* **35**, 509, 1930) has recently developed the theory of the origin of ferromagnetism which had already been treated by Heisenberg and by Bloch (*Zeit. f. Phys.* **57**, 445, 1929), based on the "interaction" of electrons as pictured on Schrödinger's theory. He discussed the relation between ferromagnetism, electrical conduction and cohesion in metals. The experiments of Dorfmann, Jaanus, and Kikoin (*Zeit. f. Phys.* **54**, 277, 1929) on the Thomson effect in nickel indicate that the same electrons are responsible for conduction and for ferromagnetism. Fowler and Kapitza (*Proc. Roy. Soc. Lond.* **124A**, 1, 1929) applied Heisenberg's theory to the phenomena of magnetostriction and of the large change in specific heat and in volume at the magnetic transformation point.

Becquerel and de Haas (*Proc. Roy. Soc. Amst.* **32**, 578, 1929) have experimentally verified the relation between paramagnetic susceptibility and temperature which is predicted by the quantum theory and which is different from that derived on classical assumptions. The quantum theoretical calculation of the paramagnetic susceptibilities of the elements of the rare earth and iron groups has been improved by Van Vleck and Frank (*Phys. Rev.* **34**, 1494, 1929). Gans (*Naturwiss*, **18**, 184, 1930) has reported that at very high fields the saturation value of magnetization of permalloy decreases, due to diamagnetism. Forrer (*Jl. Phys.* **1**, 49, 1930) has investigated the ferromagnetic and paramagnetic properties of a series of alloys near the magnetic transformation temperature.

A number of papers deal with the change of resistance of metals in a magnetic field; these include measurements by McKeehan on permalloy (*Phys. Rev.* **35**, 657, 1930), Vilbig on iron, nickel and steel (*Arch. f. Elekt.* **22**, 194, 1929), Kapitza on about thirty metals in very high fields (*Proc. Roy. Soc. Lond.* **123A**, 292, 1929), and Meissner and Scheffers on gold at very low temperatures (*Phys. Zeit.* **30**, 827, 1929).

Another attempt has been made, this time by Stearns (*Phys. Rev.* **35**, 292, 1930), to detect a change in the X-ray reflecting powers of ferromagnetic materials when they are magnetized. Although the sensitivity of the test is greater than ever before, the result is again negative and indicates that ferromagnetism should be identified with the spinning electron.

The average size of the discontinuities in magnetization (Barkhausen effect) have been determined by Bozorth and Dillinger (*Phys. Rev.* **35**, 733, 1930). Preisach (*Ann. d. Phys.* **3**, 737, 1929) has confirmed the earlier work of Bozorth in showing that practically the whole change in magnetization takes place discontinu-

ously, and has also shown that the size of the larger discontinuities may be greatly changed by tension and torsion.

The properties of single crystals of ferromagnetic materials have again been the object of several researches. Kaya has found that in cobalt the hexagonal axis coincides with the direction of easy magnetization (*Tohoku Rep.* **17**, 1157, 1928). Potter has prepared a single crystal of a Heusler alloy and studied its structure by X-rays, as well as its magnetic properties. Iron and nickel crystals have been studied further by Foster (*Phys. Rev.* **33**, 1071, 1929), Gries and Esser (*Stahl und Eisen* **49**, 879, 1929), Sizoo (*Zeit. f. Phys.* **57**, 106, 1929), and Zeigler (A. I. M. E. Pub. No. 273 C 43, 1930). The sharp corners in the magnetization curve originally reported by Gerlach have been accepted as real by Sizoo and by Gries and Esser, but questioned by Foster and Bozorth (*Nature* **125**, 525, 1930).

Thin films of iron, cobalt, and nickel, deposited on non-magnetic supports, have been investigated by Howie (*Phys. Rev.* **34**, 1440, 1929) and by Tyndall and Wertzbaugher (*Phys. Rev.* **35**, 292, 1930). Howie explains many of the results of previous investigators as due to the relative thermal expansions of the films and their supports on which they were deposited at temperatures other than that at which their magnetic properties were measured.

The magnetic moment of some ferromagnetic atoms have been found to be greater in some alloys than in the pure metal. Weiss, Forrer, and Birch (*C. R.* **189**, 663, and 789, 1929) have shown again that this occurs in iron-cobalt but not in cobalt-nickel alloys. Constant (*Phys. Rev.* **34**, 1217, 1929) has shown it to occur in platinum-cobalt alloys and Kaya and Kussmann (*Naturwiss* **17**, 995, 1926) in manganese-nickel alloys.

The magnetic properties of Heusler alloys, as related to their crystal structure, have been further elucidated by Valentiner and Becker (*Zeit. f. Phys.* **57**, 283, 1929) and by Doerum (*Avh. Oslo.* No. 10, 1929) as well as by Potter as mentioned above.

Reviews of many of the aspects of magnetism have been written by Gerlach (*Jl. Phys.* **10**, 273, 1929) and by Bruninghaus (*Rev. Gen. Elec.* **25**, 197 and 237, 1929). A small important book, "Magnetism,"[4] describing the theoretical significance of the facts of dia-, para-, and ferro-magnetism, has recently been published by Stoner.

Electrical Conduction in Solids

Conduction in solids plays a part in practically all problems with which the electrical engineer has to deal, but no entirely satisfactory explanation of the phenomenon is as yet at hand. The theory of metallic conduction which seems to promise most has been developed by Sommerfeld, and is summarized by Darrow in the *Physical Review* Supplement, Vol. 1, 1929, p. 90; by Samuel in the *Electrotechnische Zeitschrift*, Vol. 50, 1929, p. 1481; and by Houston (including his own contributions) in A. I. E. E. Trans. **49**, 30, 1930, p. 795. Houston, in the *Physical Review*, Vol. 34, 1929, p. 279, showed how a law for the dependence of resistance on temperature could be obtained from the theory.

The marked decrease in resistance as the temperature of − 273 deg. cent. (0 deg. K.) is approached may at some future time be the key which will allow us to discover the nature of conduction. Bloch (*Zeit. f. Physik.* **59**, 208, Jan. 2, 1930) considering theoretically both the energy changes and the scattering of the electrons as they collide with the atoms of the metallic crystal, found that the electrical resistance at very low temperatures should vary as the fifth power of the absolute temperature. This is checked by experimental results only moderately well, and Bloch attributes the lack of closer agreements to the imperfection of the theoretical assumptions made in his derivation.

The phenomenon of superconductivity (a drop to extremely low resistance in the immediate neighborhood of the absolute zero) is of especial interest. De Haas, at the University of Leyden, who published much on this subject during the year, found that certain alloys, having constituents that were not superconducting, were themselves superconducting. Kapitza (*Proc. Roy. Soc.* **123**, 342, 1929) and Bartlett (*Nature* **123**, 869, 1929) also have discussed superconductivity.

Kapitza (*Proc. Phys. Soc. Lond.* **123**, 292, 1929) and Meissner and Scheffers (*Phys. Zeit.* **22**, 826, 1929) have studied the changes in electrical conductivity in strong magnetic fields. Bloch (*Zeit. f. Phys.* **53**, 216, 1929) has applied the quantum mechanics to this general problem; his conclusions are criticised by Frank (*Zeit. f. Phys.* **60**, 682, 1930). Auwers (*Naturwiss.* **45**, 867, 1929) has also treated the problem theoretically.

With regard to the conductivity of crystals, Smekal (*Zeit. f. Phys. Chem.* 3B, 162, 1929) brought forward more evidence in favor of his point of view that ionic conduction takes place at the boundaries of rifts in the crystal and that electronic conduction occurs inside the crystal. His theory has been hotly contested by Jost, many papers being published in the *Zeitschrift für Physik* and in the *Zeitschrift für Physikalische Chemie*. A list of titles is found in Jost's latest rejoinder in the latter journal for March, 1930.

Thin films have been technically applied as high resistances (*Perucca*, C. R. **189**, 527, 1929 and *Ann. d. Phys.* **4**, 252, 1930; and Kruger, *Zeit. Tech. Phys.* **10**, 495, 1929), and also as fuses (*Jl. Sci. Inst.*, **6**, 102, 1929). Ingersoll and Hanawalt (*Phys. Rev.* **34**, 972, 1929) investigated the conductivity of evaporated and sputtered nickel films. They found in the sputtered films a large gas content, which was liberated at 300 to 400 deg. cent., at which temperature the films became magnetic and better conducting. The gas content of the evaporated films was less. Braunbek (*Zeit. f. Phys.* **59**, 191, Jan. 2, 1930) applied some old results of Volmer

4. Methuen, London, 1930.

and Estermann and found that the specific resistance of a mercury layer condensing on a glass surface decreases with the amount on the surface very rapidly at first, and then more slowly, to a constant value.

Schottky and Deutschmann (*Phys. Zeit.* **30**, 839, 1929) studied the potential distribution in a copper oxide rectifier.

Herzfeld (*Phys. Rev.* **34**, 791, 1929) has published an article on the influence of surface conditions and space-charge on the conductivity of poor conductors, which may repay study.

Photoelectricity

Photoelectricity received a marked impetus during the year through the growing importance of the applications of the photoelectric cell. Among the major fields of applications may be mentioned the talking moving pictures, color television, and two-way television, the latter two achieved during 1929 and 1930 respectively; and television broadcasting which is being quite extensively developed.

Very material increases in the sensitivities of photoelectric cells have been brought about by the formation of composite surfaces, or compounds of the photosensitive alkali metals previously employed, on the cathodes of the cells. More sensitive cells of this nature (such as those obtained with sodium and potassium on the cathode) were used in daylight television and in the wire television developments referred to above; they were reported on by Olpin (*Phys. Rev.* **33**, 1081, 1929). Cells utilizing caesium as the alkali metal have been produced by Koller (*Phys. Rev.* **33**, 1082, 1929, and *J. O. S. A.* **19**, 135, 1929) and by Zworykin and Wilson (*J. O. S. A.* **19**, 81, 1929). The type described by Koller (Cs O) seems to respond more strongly to light at the extreme long wavelength limit of the visible spectrum than does any other cell at present known. Campbell and Ritchie have written a valuable book, "Photoelectric Cells,"[5] dealing at length with their construction and operation.

Passing from the technical to the scientific side of the subject, it is certainly necessary to note the study of the long wavelength limit of thin alkali metal films, made by Ives and Olpin (*Phys. Rev.* **34**, 117, 1929). This limit depends on the thickness of the film; and the highest wavelength that it reaches, as the thickness of the film is varied, was found by these authors to coincide with the first line of the principal spectrum series of the free atom, corresponding to the resonance potential. Suhrmann and Thiessing (*Zeit. f. Phys.* **55**, 701, 1929), Campbell (*Phys. Zeit.* **30**, 537, 1929), and Fleischer and Teichmann (*Zeit. f. Phys.* **61**, 227, 1930) also studied these thin films, being interested especially in potassium adsorbed on platinum. Lawrence and Linford gave a paper before the American Physical Society, April 25, 1930, on the influence of intense electric fields on the photoelectric behavior of such films.

5. Isaac Putnam and Sons.

Thermionics

The past year has witnessed no outstanding developments in that branch of electrophysics which deals with the emission of positively and negatively charged particles from heated bodies.

Many years ago Richardson developed a fundamental relation between the saturation electric current due to the emission in question and the absolute temperature. This law in its mathematical expression was $i = A\,T^2\,e^{-b/T}$, where A and b were thought to be material constants independent of T. There has been in the intervening years much discussion and argument as to just what values A and b should or do have, especially for electron emission. During the past year, Fowler (*Proc. Roy. Soc.* **A 122**, 36, 1929) considered the value of A for electron emission from the standpoint of the new statistics; and Zwikker (*Phys. Zeit.* **30**, 578, 1929) tried to establish a linear relation between log A and b for surfaces of a metal with differing degrees of contamination.

Wahlin (*Phys. Rev.* **35**, 653, March 15, 1930) and Smith (*Phys. Rev.* **35**, 381, February 15, 1930) have both continued work on the emission of positive ions from hot metallic filaments.

The efficiency of an electron emitter, such as the filament in a vacuum tube, may be rated in milliamperes of electrons furnished per watt of heating energy. It has been found that, over a range of temperatures, thin films of so-called "active" metals are more efficient thermionically than metals in bulk. Filaments based on this result are used in practically all vacuum tubes as the source of electrons, and are for that reason the subject of much study. Thus the thermionic and other properties of thorium films on tungsten were investigated by Andrews (*Phys. Rev.* **33**, 454, 1929), by Reynolds (*Phys. Rev.* **35**, 158, January 15, 1930) and by Brattain (*Am. Phys. Soc.*, April, 1930). The Richardson constants of thin film cathodes formed by distillation were obtained by Espe (*Zeit. f. Tech. Phys.* **10**, 489, 1929). Becker (*Phys. Rev.* **34**, 1323, 1929) published the results of an extensive series of experiments on Wehnelt (Ba O, Sr O) oxide coated filaments; he found that the high activity is due to a thin film of metallic barium or strontium on the surface of the oxides, and that this metallic barium or strontium was produced by electrolysis of the oxides. Riemann and Murgoci (*Phil. Mag.* **9**, 440, March, 1930) found a parallelism between the variations, during the life of each oxide-coated cathode, of the electrical conductivity and of the thermionic emission. On the technical side a new core (Konel) for this latter type of filament has been introduced by the Westinghouse Company; and there were articles on the development of such oxide-coated filaments by Hodgson, Harley and

Pratt (*Jl. I. E. E.* **67**, 762, 1929) and by McNabb (*J. O. S. A.* **19**, 33, 1929).

The statistical variation in thermionic emission leads to minute erratic changes in the currents obtained from devices employing the emission. These minute changes are known under the name "shot effect." Williams and Huxford have recently studied the shot effect for positive ions. Williams and others attribute a portion of the fluctuations in electron space current from Wehnelt cathodes at low potentials, such fluctuations being larger than those for metallic emitters, to the presence of positive ions. Smith has also studied the modification of the shot effect for electrons by positive ions.

Auto-Electronic Discharge

The "pulling out" of the electrons by high fields is a source of great worry to the designers of high voltage vacuum tubes, and probably enters into most high voltage discharge phenomena. A number of papers have been published during the past year on the subject. Bridgman's note in the *Physical Review*, Vol. 34, 1929, p. 1411, is an interesting analysis of the phenomenon. Houston (*Phys. Rev.* **33**, 361, 1929) applied the methods of wave mechanics to the problem of the dependence of the effect on temperature. Millikan and Lauritsen investigated the same subject (*Phys. Rev.* **33**, 598, 1929), finding the electron-emission to be independent of temperature up to 1100 deg. K. De Bruyne was of the opinion (*Phys. Rev.* **35**, 172, Jan. 15, 1930) that no temperature variation at all had been proven as yet. He also considered the effect of contaminating layers of caesium and of nitrogen on tungsten (*Proc. Camb. Phil. Soc.* **25**, 347, 1929), and Gosling, Fowler, and Stern were others who studied this case. (*Proc. Roy. Soc.* 1929 and *Proc. Camb. Phil. Soc.* **25**, 454, 1929).

Vacuum Tubes

There are a number of different angles from which one may view a vacuum tube. It may be considered merely as a piece of apparatus, an instrument which performs certain functions; it may be looked upon as an addition to (and sometimes a considerable complication of) an existing electrical circuit; or the various physical phenomena involved in its design, manufacture, and operation may be studied. It is probably from the last mentioned standpoint that the justification for including the subject in "electrophysics" would originate. Little apology is needed, however, because of the widespread interest in vacuum tubes and their applications, and the intimate relationship to previous topics discussed and the one to follow.

The latter part of 1928 and the whole of 1929 proved a noteworthy period in the development of the type of apparatus commonly known under the generic term of "vacuum tubes." Foremost in importance was probably the development of hot cathode tubes containing gases at pressures of 0.001 mm. to several cm. The presence of this amount of gas is so much the predominant feature in the action of the tube that this division of the subject may best be discussed under "Gas Discharges" (see below).

In the case of true vacuum tubes, considering the smaller ones first, developments have been along the line of multi-grid tubes. The pentode or three-grid tube in both the space-charge screen grid and the screen grid plate shielding grid circuits, has received attention, and a space-charge grid tube with the space-charge grid co-planar with the control grid has been developed. This latter tube has low plate resistance, combined with a high undistorted output, and appears to be a very important development (Pidgeon and McNally, *Proc. I. R. E.* **18**, 266, Feb. 1930). The field of small vacuum tubes as a whole was marked by increasing stringency in the requirements of the circuits in which they were used.

Large power tubes which deliver as much as 100 kw. have been made and operated in broadcasting sets. A double-ended power tube for short waves, 15 meters, is being used in the transatlantic radio service.

Tuve, Breit, and Hafstad have succeeded in constructing a vacuum device consisting of a number of electrodes in cascade which withstood 1,400,000 volts between extreme terminals (*Phys. Rev.* **35**, 66, January 1, 1930).

Among the papers published on vacuum tube designs and circuits were:

1. "Effect of End Losses on the Characteristic of Filaments of Tungsten and Other Materials," Langmuir, McLane and Blodgett, *Phys. Rev.* **35**, 478, March 1, 1930.
2. "Calculation of the Characteristics and Design of Triodes," Kusunose, *Proc. I. R. E.* **17**, 1706, 1929.
3. "Microphonic Improvements in Vacuum Tubes," Rockwood and Ferris, *Proc. I. R. E.* **17**, 1621, 1929.
4. "Noise in Vacuum Tubes and the Attached Circuits," Llewellyn, *Proc. I. R. E.* **18**, 243, February, 1930.
5. "Output Power Obtained from Vacuum Tubes of Different Types," Pidgeon and McNally, *Proc. I. R. E.* **18**, 266, February, 1930.
6. "Circuit Analysis Applied to the Screen Grid Tube," Nelson, *Proc. I. R. E.* **17**, 320, 1929.
7. "Mathematical Theory of the Four-Electrode Tube," Brainard, *Proc. I. R. E.* **17**, 1006, 1929.
8. "Equivalent Circuits of a Triode," Chaffee, *Proc. I. R. E.* **17**, 1633, 1929.
9. "Modulators from a Physical Viewpoint," Peterson and Llewellyn, *Proc. I. R. E.* **18**, 38, January, 1930.

A new journal, *Electronics*, published by McGraw-Hill, was started in April, 1930, to take care of this subject and of thermionics and photoelectricity.

Gas Discharges

The understanding of the physical characteristics of gaseous conduction has been advanced by a number of theoretical and experimental researches during the year.

J. J. Thomson (*Phil. Mag.* **8**, 393, 1929) has worked out new formulas for the cathode fall of potential, length of dark space, and current density in the electric discharge through gases. He has shown that radiation, as well as collision, plays an important part in discharge phenomena. Brown and E. E. Thomson have found that the potential gradient in the cathode dark space is very nearly uniform.

The effect of positive and negative space charges in the gas and at the electrodes has been made more clear by work done by Langmuir. Langmuir and Tonks (*Phys. Rev.* **34**, 876, 1929) have discovered and studied a very high frequency oscillation in the electron atmosphere of an ionized gas, called by them "plasma" oscillation. This oscillation is responsible for the abnormally high electron velocities observed by Langmuir in such a gas.

The total ionization produced by an electron has been measured again by Kulenkampff and by Eisl. The latter, claiming the highest accuracy yet attained, finds for the average amount of energy lost by an electron per ion produced in air the value $32.2 \pm .5$ electron volts.

The mechanism of recombination of ions and electrons has been discussed in the light of present day knowledge by Loeb and by Seeliger. One of the most interesting discoveries of the year was made by Bergen Davis and A. H. Barnes (*Phys. Rev.* **35**, 217, Feb. 1, 1930) who find that electrons and α-particles combine only when the electrons have one of certain definite velocities with respect to the α-particle. These results, which have attracted wide attention, are still under debate.

The study of the Ramsauer effect, the abnormally small apparent area of certain molecules to slow electrons, has been continued by Brüche, Kollath, Holtsmark, Jones, Ramsauer and others.

By means of a Langmuir probe Nottingham (*Jl. Frank. Inst.* **207**, 299, 1929) has measured the potential distribution in a copper arc, with interesting results; while Mackeown has considered arcs theoretically on the basis of certain simplifying assumptions.

The ignition and form of spark in a large number of combustible gas mixtures has been studied by Tereda and collaborators (*Sci. Papers*, Inst. of Phys. and Chem. Res., Tokyo). The activation of nitrogen by electric discharge has received a good deal of attention, and a number of papers are devoted to the synthesis of compounds by cathode rays or by the glow discharge. Brewer and Westhaven (*Jl. Phys. Chem.* **33**, 883, 1929), for instance, found that the synthesis of ammonia is initiated by the positive ions in the discharge.

The importance of metastable atoms in affecting sparking potentials in noble gases has been brought out (Penning, *Zeit. f. Phys.*, 1929). Electrons are freed from electrodes by the impacts of metastable atoms and thus strongly influence currents to electrodes in ionized gases (Uyterhoven, *Phys. Rev.*, Ratner, *Proc. Nat. Acad.*, Oliphant, *Proc. Roy. Soc.*, 1929).

The manner of extinction of alternating current arcs is being actively studied. The efficacy of the oil breakers is said to be due to the generation of gas from the oil and the rapid mixing with the arc (Slepian, A. I. E. E. TRANS. **49**, 421, 1930). Improved utilization of oil as a deionizing means has been achieved (Baker and Wilcox, A. I. E. E. TRANS. **49**, 431, 1930). Gas blasts have been effectively used as deionizing means in high voltage circuit interrupters (Biermann, *E. T. Z.*, 1930).

The discharges started by high voltage surges have been the subject of considerable work such as that of Lee, Rogowski, McEachron and Goodwin, Lissner, and Berger. Both Rogowski and Beams have found that the time lag in such discharges is extremely short, so short that according to von Hippel and Franck (*Zeit. f. Phys.*, 1929) the Townsend theory of the initial glow discharge cannot apply in these cases. Paavola, under not very different conditions, finds good agreement with the story of Townsend. Lawrence and Dunningham (*Phys. Rev.*, 1930) believe that early development of very high temperatures, with possible thermal ionization, is also indicated.

In the case of lightning discharges, a considerable mass of data must be accumulated over a period of time before we shall have conclusive proof of the voltage range of induced surges and of those due to the main or auxiliary branches of direct strokes.

While much development has been reported in the applications of gaseous conduction, only a few which present outstanding novelty and promise will be mentioned.

The importance of gaseous tubes with hot cathodes is increasing rapidly. Thus the hot cathode mercury vapor tube describedby Hull, (A. I. E. E. TRANS. **47**, 798, 1928) is rapidly displacing the kenotron in practise due to superior performance and lower cost. Gaseous tubes in which the starting of the current is controlled by a grid are finding almost countless applications in control work of all types. The thyratron, developed by Hull, and the grid glow tube, developed by Knowles, are of this type.

A higher-power arc rectifier has been developed by Toulon, in which the arc takes place in air at atmospheric pressure. The arc is initiated each cycle by a timed spark, and the device is called the pilot-spark rectifier.

A daylight lamp in which part of the light comes from the arc between a mercury surface and a hot tungsten filament has been described by Strickland.

PROPAGATION OF ELECTRIC WAVES

Continued progress has been made during the past year in the study of the propagation of short waves. Long time echo signals having delays up to 4 minutes 20 seconds have been reported by Hals, and a number of other observers have found echoes with time lags up to 30 seconds. Observations by Galle and Talon during

the solar eclipse of May 9 (reported in *C. R.*, Jan. 6, 1930) were carried out at a wavelength of 25 m., several other investigators have used wavelengths of the order of 30 m. A low group velocity as the cause of long time echoes has been considered by a number of authors; thus Breit has shown that if the refractive index of the Kennelly-Heaviside layer decreases exponentially with height it is possible that this effect would be produced (*Proc. I. R. E.* **17**, 1508, 1929). In this explanation, absorption is tentatively ignored, an assumption which many workers regard as unjustifiable. Pederson believes that echoes having a greater delay than ten seconds cannot be due to waves propagated entirely within the earth's atmosphere, and concludes that echoes with delays up to one minute are probably due to propagation along or reflections from "Störmer bands" of electrons within the magnetic field of the earth, while echoes with greater delay must be due to bands of ions located so far away as to be beyond the influence of the earth's magnetic field (*Proc. I. R. E.* **17**, 1750, 1929).

Renewed interest has been shown in theoretical and experimental investigations of the surface wave (ground wave), particularly that which is set up near short-wave transmitting antennas. Considerable attention has also been given to the "optical" properties of the earth for wavelengths in the radio spectrum.

American and European investigators have collected many data which throw light on the propagation of short waves, such as diurnal variations in layer height, effect of magnetic storms, and short-time echo signals over both long and short distances of transmission. An interferometer method of measuring slight changes in the optical path of waves reflected by the ionized region in the upper atmosphere has been devised by Hafstad and Tuve (*Proc. I. R. E.* **17**, 1786, 1929).

Magnetic storms are accompanied by severe disturbances in short wave transmission. It has been found that at such times the height of the Kennelly-Heaviside layer is materially increased. This has been attributed to unusual solar activity at such times. Several investigations to determine the correlation in greater detail are under way.

Abroad, particularly in Germany, there has been great activity in connection with very short waves from a few centimeters to ten meters in length. Methods of generating and modulating relatively large amounts of power in this range had been devised and the propagation properties of the waves studied. It is found that these waves follow substantially an optical path between transmitter and receiver, that the attenuation in space is very low, but that the ground wave is absorbed with extreme rapidity. The sky wave is unaffected by fog, rain, sunlight, or darkness.

In addition to the large amount of experimental work on short wave propagation, progress has been made in the study of the ionized regions above the earth from the point of view of the physics of the upper atmosphere. Notable in this connection is the work of Hulburt and others in the Naval Research Laboratories.

Electromagnetic Theory; Electric and Magnetic Fields

A thoroughgoing discussion of the electromagnetic theory is found in "The Electromagnetic Field" by Mason and Weaver. Leigh Page says, "It constitutes unquestionably the foremost critical study of electromagnetic theory in the English language."

Heisenberg and Pauli (*Zeit. f. Phys.* **56**, 1, 1929) and Oppenheimer (*Phys. Rev.* **35**, 461, March 1, 1930) are continuing their researches on remodeling the fundamental theory. Kaplan and Murnaghan also published an article, quite mathematical in nature, "On the Fundamental Constitutive Equations in Electromagnetic Theory" in the *Physical Review* for April 1, 1930.

Passing to a much less abstract phase of the subject, namely, to waves on wires, there is an interesting treatment of propagation along wires from this standpoint by Aguillon in *Annales des P. T. T.* Vol. 17, 1928, p. 846, and Vol. 18, 1929, p. 89. Karapetoff discussed a *Graphical Theory of Traveling Waves between Parallel Conductors* in the Jl. of the A. I. E. E. for February, 1929. Ohashi (*E. N. T.* **6**, 1, 1929) considered the "Disturbing Effect of Traveling Waves and the Mutual Influence of Telegraph Lines," taking the lines to be both inductively and capacitatively coupled.

The experimental study of traveling wave phenomena on transmission lines has been advanced by the use of truck mounted cathode ray oscillographs and portable impulse generators, rated at 1,000,000 volts. Much work done along this line was reported in several papers at the Midwinter Convention.

Closely allied to the paper by Ohashi mentioned above are a large number treating disturbances in one electric line due to another—or to waves from a distance. Among these may be mentioned:

1. "Electrostatic Influence of a Power Line on a Telephone Circuit," Picault, *Annales des P. T. T.* **18**, 885, 1929.
2. "Disturbances Induced in a Communication Circuit by Traction Currents," Rüdenberg, *Jl. Teleg.* **53**, 145, 169, 1929.
3. "Electromagnetische Störungen," Schindelhauer, *E. N. T.* **6**, 231, 1929.
4. "Mutual Inductance Measurements on Conductors with Earth Return," Klewe, *E. N. T.* **6**, 467, 1929.
5. "Analysis of Irregular Motions with Applications to the Energy Frequency Spectrum of Static and of Telegraph Signals," Kenrick, *Phil. Mag.* **7**, 176, 1929.
6. "Power Circuit and Inductive Interference with Telephone and Telegraph Systems," Huth, *Trans. S. Af. I. E. E.* **20**, 115, 1929.
7. "Unbalance of Telephone Lines and Circuits Subject to Inductive Disturbances," Roehmann, *T. F. T.* **18**, 18, 1929.
8. "Mutual Impedance between Adjacent An-

tennas," Englund and Crawford, *Proc. I. R. E.* Aug., 1929.

9. "Magnetic Disturbances and Long Distance Reception," Kennelly, *Electronics*, April, 1930.

10. "Uber die induktive Beeinflussung von Schwachstromleitungen durch Starkströme," Schiller, *Arch. f. Elekt.* **23**, 217, 1929.

11. "Reciprocal Theorems in Radio Communication," Carson, *Proc. I. R. E.* **10**, 952, 1929, and an extensive commentary on the subject by Ballantine in the same issue.

Some papers which touch the power engineer probably as closely as the transmission engineer are:

1. "Distribution of Electric and Magnetic Fields," Hague, *Elec.* **102**, 185 and 315, 1929.

2. *Flux Linkages and Electromagnetic Induction in Closed Circuits*, Bewley, JL. OF THE A. I. E. E. **48**, 216, 1929.

3. *Forces on Magnetically Shielded Conductors*, Morecroft and Turner, JL. OF THE A. I. E. E. **48**, 25, 1929.

There should also be included here the series of papers which is probably familiar to many A. I. E. E. members, namely, that comprising the symposium on *Shielding in Electrical Measurements* held at the A. I. E. E. Summer Convention in 1929.

Miscellaneous

The year has seen notable advances in piezo-electric oscillators. Marrison (*Proc. I. R. E.* **17**, 1103, 1929) has developed a constant frequency oscillator of this nature that will maintain its frequency constant to within one part in 10^7 over considerable time intervals. The pecularities of parallel cut quartz crystals, such as non-oscillating thicknesses, doublet resonant frequency, etc., have been explained on a rational basis, and quartz crystals with a zero-temperature coefficient for frequency have been obtained by using special proportions Lack (*Proc. I. R. E.* **17**, 1123, 1929).

The subject of direct current amplifiers and their application to various types of measurement has been a live one during the past year. There have been papers by Brentano (*Zeit. f. Phys.* **54**, 571, 1929), Eglin (*J. O. S. A.* **18**, 393, 1929), Carwile and Scott (*Phil. Mag.* **34**, 161, 1929), Razek and Mulder (*J. O. S. A.* **18**, 460, 1929 and **19**, 390, 1929), and Rasmussen (*Ann. d. Phys.* **2**, 357, 1929).

The application of mathematical methods to electrcial engineering, especially to electrical circuits, was of interest to many. The American Mathematical Society conducted a symposium on "Differential Equations of Engineering" in December. At this meeting the question of establishing a journal of applied mathematics was discussed. Two important books dealing with circuits were "Operational Circuit Analysis" by Bush, and "Heaviside's Operational Calculus as Applied to Engineering and Physics" by Berg. Some other followers of Heaviside, with the subjects of their articles, may be noted:

1. "Heaviside's Fractional Differentiation," Sumpner, *Phys. Soc. Proc.* **41**, 404, 1929.

2. "Extension of Heaviside's Operational Calculus for Invariable Systems," Van der Pol, *Phil. Mag.* **7**, 1153, 1929.

3. "A Generalization of Heaviside's Expansion Theorem," Pennell, *Bell System Technical Journal*, **8**, 482, 1929.

4. "Operator Solution of Linear Differential Equations," Van der Pol, *Phil. Mag.* **8**, 861, 1929.

5. "Differential Equations as a Foundation for Electric Circuit Theory," Fry, *Am. Math. Monthly* **36**, 499, 1929.

6. "Operational Methods in Wire Transmission Theory," Josephs, *P. O. E. E. Jl.* **23**, 60, April, 1930.

Physics as a whole has been extending its sphere of influence into the biological sciences. In this extension, many studies are being made, on subjects such as the electrical currents developed by nerves and the electrical characteristics of cell surfaces, which may be classed under the domain of the applications of electrophysics—perhaps one might say under electrobiology. Such investigations are hopeful indications of an advance in knowledge of physical processes in this division of the sciences.

Values of the general physical constants have been published by Birge in the *Physical Review Supplement*, July, 1929. Volumes V and VI of *International Critical Tables* were also published in the past year. Volume VI contains much of interest to the electrophysicist, the table of contents including electronics and gas conduction, dielectric properties, electrical conductivity, pyro- and piezo-electricity, thermo-electricity, electrolytic electromotive forces, and magnetism.

In case the electrical engineer wishes to pursue studies in a particular field in present day physics or wishes to renew his knowledge of some branch of the science, he will find helpful summaries of the theoretical and experimental conclusions to date in a series of articles entitled "Some Contemporary Advances in Physics" by K. K. Darrow, published in the *Bell System Technical Journal*, and also in the numbers of the *Reviews of Modern Physics*. The latter periodical was started (under the name of the *Physical Review Supplement*) during the past year for the purpose of providing general surveys for those who were not specialists in the subjects discussed.

For drawing up the above summary, information has been furnished by members of the Electrophysics Committee, and in addition contributions of material have been received from Messrs. R. M. Bozorth, K. K. Darrow, J. M. Eglin, J. B. Johnson, and J. C. Schelleng. The chairman is especially indebted to Dr. J. M. Eglin for assistance in compiling the report.

ELECTRICAL MACHINERY*

To the Board of Directors:

The Committee on Electrical Machinery takes pleasure in submitting the following report on its work during the past year. The report is divided into two sections, the first dealing with organization and policies, and the second with the progress of the art.

Part I.—Organization and Policies

The Electrical Machinery Committee is organized with five permanent subcommittees, with the following memberships:

Subcommittee on Synchronous Machinery

S. L. Henderson, Chairman, B. L. Barns, C. M. Gilt, C. F. Harding, J. A. Johnson, H. C. Louis, O. K. Marti, A. M. Rossman, O. E. Shirley, R. B. Williamson.

Subcommittee on Transformers

V. M. Montsinger, Chairman, Raymond Bailey, W. H. Cooney, W. M. Dann, J. A. Johnson, H. C. Louis, J. H. Paget, J. F. Peters, Philip Sporn.

Subcommittee on Induction Machines

H. B. Dwight, Chairman, A. B. Craig, J. L. Hamilton, C. J. Koch, F. Miller, C. A. Price, O. C. Schoenfeld.

Subcommittee on D. C. Machines

H. L. Zabriskie, Chairman, J. Bourath, J. L. Burnham, H. B. Dwight, Jesse B. Lunsford, A. M. MacCutcheon, E. P. Nelson, R. W. Owens, W. H. Powell, W. I. Slichter, J. G. Tarboux.

Subcommittee on Mercury Arc Rectifiers

E. L. Moreland, Chairman, H. L. Andrews, L. D. Bale, A. E. Bettis, H. D. Braley, O. K. Marti, E. B. Paine, D. W. Proebstel, E. B. Shand, H. C. Sutton.

Annual Report

C. M. Gilt.

The Committee has dealt with two principal subjects, standards and papers.

Standards

During the year the Committee has studied many proposed changes in the existing A. I. E. E. Standards, and has recommended to the Standards Committee the adoption of alterations and additions relative to the following subjects or paragraph numbers:

Standard No. 5: D-C. Rotating Machines, Generators and Motors

A new definition of a two winding synchronous converter.

Revisions of paragraphs 5-356 (a) and 5-367 (a) relating to field rheostat losses.

*COMMITTEE ON ELECTRICAL MACHINERY:

P. L. Alger, Chairman,
E. B. Paxton, Secretary,

L. F. Adams,	C. F. Harding,	L. W. McCullough,
B. L. Barns,	S. L. Henderson,	V. M. Montsinger,
W. M. Dann,	L. F. Hickernell,	E. L. Moreland,
H. B. Dwight,	J. Allen Johnson,	F. D. Newbury,
W. J. Foster,	H. C. Louis,	R. W. Owens,
C. M. Gilt,	A. M. MacCutcheon,	A. M. Rossman,
W. S. Gorsuch,	O. K. Marti,	R. B. Williamson,
A. L. Harding,		H. L. Zabriskie.

Presented at the Summer Convention of the A. I. E. E., Toronto, Ont., Canada, June 23-27, 1930. Complete copy upon request.

Standard No. 7: Alternators, Synchronous Motors and Synchronous Machines in General

New definitions as follows:
Synchronous Reactance
Potier Reactance
Resistance Drop
Potier Reactance Drop
Potier Impedance Drop
Electrical Degree
Short Circuit Ratio
Terminal Voltage
Induced Voltage
Excited Voltage
Distortion Factor

A new paragraph relating to a method of calculation of field current at full load.

Revisions of paragraphs 7-457 (a), 7-461 (a), and 7-474 (a) relating to field rheostat losses.

Standard No. 9: Induction Motors and Induction Machines in General

New paragraphs relating to:
Allowable Voltage Unbalance
Definition of Breakdown Torque
Definition of Power Factor
Methods of Determining Power Factor

Revisions of:

Pars.	9-62	relating to slip
	9-68	relating to definitions of protected machines
	9-250	relating to break-down torque
	9-301	footnote relating to conventional efficiency
	9-310 (b)	relating to $I^2 R$ losses in the rotor
	9-312	relating to brush contact loss
	9-313	footnote relating to stray load losses.

Standard No. 13: Transformers, Induction Regulators and Reactors

Six new definitions of types of cooling.

Revisions of paragraphs 13-1, 13-215, 13-250, 13-400, 13-402, and 13-408.

Standard for Capacitors. A new standard for capacitors has been prepared and recommended to the Standards Committee for printing in report form.

The Committee desires very much to secure the early adoption of "American Standards" for all of the classes of electrical machinery, and its work on standards is all directed toward this end. At the present time, the only complete machinery standard, within the purview of this Committee, that has been approved as "American Standard" by the A. S. A. is that on synchronous converters, but the parts dealing with rating of Standards Nos. 5, 7, and 9 have also been approved as "American Standard." The complexity of the present organization for approving these standards, and the large number of interests that must be consulted before agreement can be secured, have made progress slow,

but the recent organization of a new sectional committee on Rotating Electrical Machinery is expected to facilitate matters. This new sectional committee will be responsible for the preparation of "American Standards" on all types of rotating electrical machinery, and the Committee on Electrical Machinery is actively cooperating with it.

A number of questions in regard to standards of the International Electrotechnical Commission have been referred to the committee, and reports have been made to the Advisors on Rating of the U. S. National Committee of the I. E. C. Every effort is being made to promote agreement between the I. E. C. and the American Standards.

A series of test codes for induction, direct-current, and synchronous machines and transformers is under preparation by the Committee. These codes will give explicit directions for making performance tests on electrical machinery, so that electrical tests (especially those on combined equipments, such as waterwheel generators, motor driven pumps, etc.) can be performed in a uniform way.

Papers

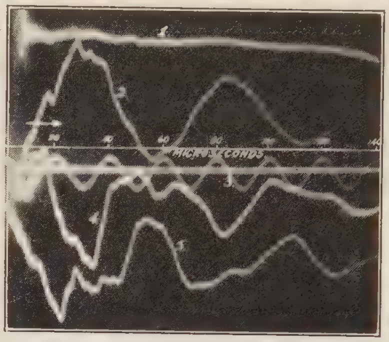
An important function of the Committee is to sponsor papers on electrical machinery, that will bring out discussion on new developments, and will properly record the progress of the art. During the past year, over 50 machinery papers have been submitted to the committee for review, and 34 have been actually presented at Institute Conventions, including twelve proposed for the 1930 Summer Convention.

There has been an increasing number of papers available during the past few years, and the need for more time for presenting, and space for recording, these papers is pressing. The Committee would like to sponsor symposiums on several aspects of electrical machinery developments during the next year or two, such as stray load losses, motor insulation, mechanical design, lightning protection of apparatus direct connected to transmission lines, reactance definitions and short circuit calculations, and mercury arc rectifiers. At the present time, the papers spontaneously submitted to the Institute occupy most of the available time at Conventions, so that there is little opportunity to develop such symposiums. The Committee, therefore, recommends that parallel sessions be held at conventions, that more papers be accepted for presentation, and that responsibility for abridging the papers and discussions to conform with the publication policies of the Institute be delegated to the committee chairmen.

Part 11—Resume of Progress of the Art

Transformers

Investigations into internal voltages in transformers have been actively continued during the year. The creation of high internal oscillations by lightning and switching surges of different kinds which were previously observed by sphere-gaps have been confirmed in the past year by the use of the cathode ray oscillograph. Fig. 1 shows oscillograms taken by the General Electric Company on ordinary core and shell types of power transformers. Fig. 2 shows oscillograms taken by the Westinghouse Company on a 140-kv. shell type power transformer. Fig. 3 shows oscillograms taken by



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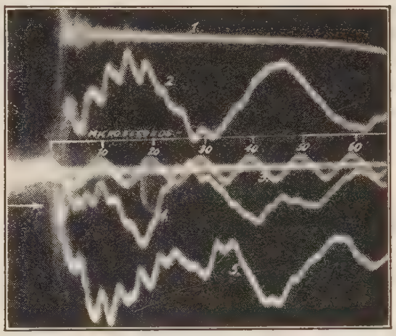


B

Fig. 1—Voltage Oscillations in Grounded Transformers

a. Core type b. Shell type

Wave No. 1 Applied voltage
Wave No. 2 At point 50 per cent from neutral end of the winding
Wave No. 4 At point 26 per cent from neutral end of the winding
Wave No. 5 At point 78 per cent from neutral end of the winding
Wave No. 3 Timing

the General Electric Company on a power transformer of the non-resonating type.

The use of equipment for changing the ratio of transformers without interrupting the load has been extended and equipment for doing this has become largely standardized and manufactured on a quantity production basis. Improvements in simplicity and sturdiness have been made.

The recent development of the General Electric Company consists of three salient parts:

1. Two heavy ratio adjusters for 9 or 11 ratios with an intermittent gear of high mechanical precision for turning first one and then another ratio adjuster to the next position.

2. Two oil-immersed, cam-operated contactors designed to remove the load from each ratio adjuster in succession during a change in ratio.

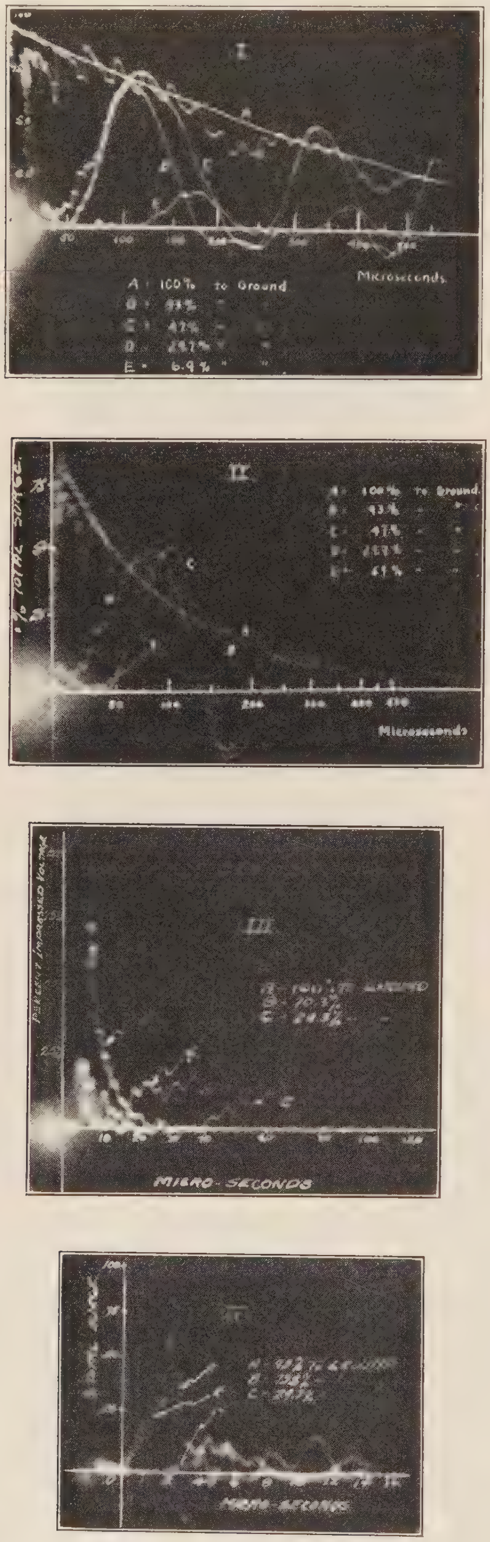


FIG. 2—OSCILLOGRAMS TAKEN BY THE WESTINGHOUSE E. & M. CO. ON A 140-KV. SHELL TYPE POWER TRANSFORMER

I Oscillations with an extremely long wave
II Oscillations with a long wave
III Oscillations with a short wave
IV Oscillations with chopped surges

3. A motor operated driving mechanism including the position indicators, limit switch, and control devices.

All transformer connections are oil immersed and are so arranged that the reactance of the circuit is the same

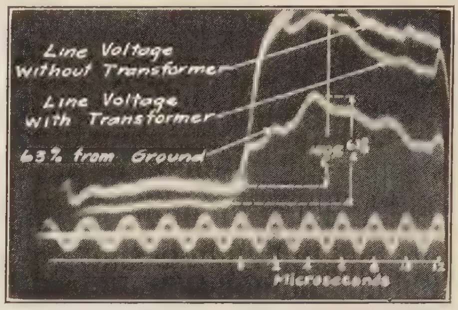


FIG. 3—NON-RESONATING TRANSFORMER

1. Voltage wave at the end of transmission line with transformer disconnected.
2 Voltage wave at the end of the transmission line with transformer connected (voltage across transformer)
3. Voltage at 63 per cent point. Crest value 63 per cent of applied voltage
Note No. 3 a practical duplicate of the shape of No. 2 in spite of the fact that the transformer was out of oil and electrostatic unbalance was created thereby

in all positions resulting in equal voltage steps. Simplicity with a minimum of connections outside the transformer tank have been the object of the design.

Fig. 4 illustrates an interesting application of up-to-date load ratio control as applied to a 20,000-kv-a., single-phase, water-cooled transformer with two secondary windings. Each winding is equipped with load ratio control for supplying individual busses. There are six of these transformers installed by the Buffalo General Electric Company forming two 60,000-kv-a. banks which were supplied by the General Electric Company.

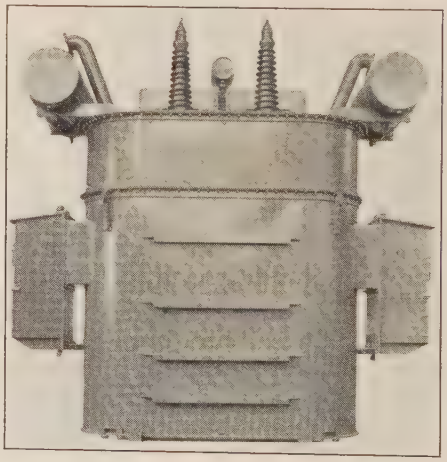


FIG. 4—A 20,000-KV-A. SINGLE-PHASE WATER COOLED, LOAD RATIO CONTROL TRANSFORMER

Built by General Electric Co. for the Buffalo General Electric Co.

A difficult problem in load ratio control was met by

the Westinghouse Company by means of a separate regulating transformer and two of their UB tap changers and a reversing switch. The transformers are used for the operation of electrical furnaces, the largest of this type constructed in this country, and are rated 6500-kv-a. single-phase, 25 cycles, 12,000/45 volts with a low voltage current of 180,000 amperes at 1¼ load. By means of the load ratio control, the secondary voltage may be varied from 30 to 60 volts in steps of approximately ½ volt each.

The use of pothead transformers, in which cables are

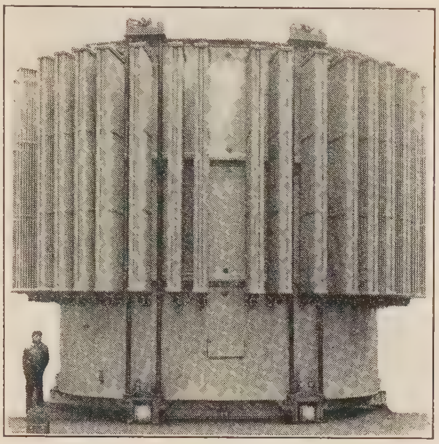


Fig. 5—A 60,000 Kv-a. Single-Phase Transformer

Built by Westinghouse E. & M. Co. for the Roseland Switching Station of the Public Service Electric & Gas Co.

brought into a pothead without external bushings, has increased, and many potheads have been equipped with internally mounted disconnecting switches which were not designed to open the transformer exciting current. Recently, however, three transformers have been built by the Westinghouse Company for the Public Service Lighting Commission of the City of Detroit in which the potheads are provided with internally mounted disconnecting switches designed to interrupt the transformer exciting current. The transformers are rated 2000-kv-a., three-phase, 60-cycles, 24,000/600-volts.

A number of transformers have been built with two secondaries having a high reactance between them in order to minimize the effect of disturbances. An example of this is the 100,000-kv-a. General Electric auto-transformer now being built to be connected to a 12,500-volt generator on the primary side with two secondaries rated 24,500 Y. On account of the unbalanced load conditions that may exist, the equivalent two winding capacity is 58,000 kv-a.

Among the notable transformer installations of the year are four Westinghouse single-phase, 60-cycle units installed in Roseland Switching Station of the Public Service Electric and Gas Company. Each transformer has four separate windings rated at 30,000, 15,000, 15,000 and 20,000 kv-a., self-cooled. The design permits the addition of forced air cooling equipment to obtain 50 per cent higher ratings. On the basis of half the sum of these forced air-cooled ratings the units are equivalent to 60,000-kv-a., two-coil transformers. The windings are for connection to lines at 220,000 volts star, 132,000 volts star, 132,000 volts star, and 11,000 volts delta. The weight of each transformer as shipped is 270,000 lb. and was the heaviest individual unit shipped on a single railroad car.

During the year the maximum size of transformers for use with mercury arc rectifiers has shown considerable increase. A number of 3000-kw. units have been built and one of 6500 kw. for a 650-volt rectifier is now being constructed by the General Electric Company. A new method of compounding has been developed by this company which results in more desirable voltage characteristics and causes the rectifier to function at practically unity power factor at normal load.

Transformers grounded through reactors are subject to high voltages at the neutral when lightning or switch-

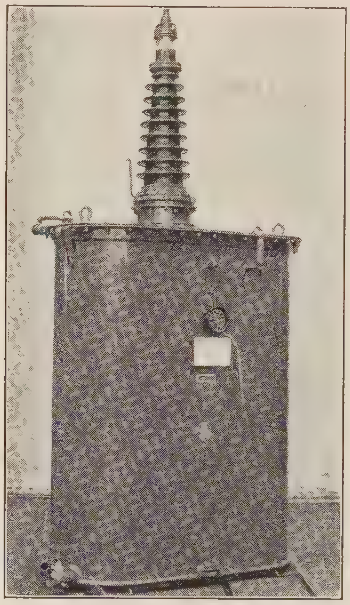


Fig. 6—Neutral Impedor

Developed by General Electric Co. to limit the voltage from transformer neutrals to ground

ing surges are applied to the line terminals. The General Electric Company has developed a grounding device called the "Neutral Impedor" for use with transformers when grounded with reactors or resistance. This device limits the voltage from neutral to ground to a predetermined value. In case such an impedor is used with a non-resonating transformer, the transient voltage distributes uniformly along the transformer winding. During the last year and a half nearly 800,000 kv-a. of transformers of non-resonating type have been built so that they can be operated with the impedor in the neutral.

Four 25,000-kv-a., 220-kv., single-phase transformers were recently shipped to the Southern California

Edison Company from the Westinghouse factory and are designed for grounding the neutral by means of a reactor. The design limits the maximum voltage of the neutral to 73 kv. above ground during a fault between line and ground. By the use of such a transformer and reactor the ground faults can be limited to a reasonably low value and the cost of installation is less than that required for transformers insulated for full voltage in both terminals.

Last year's report mentioned a standard single-phase "substation" designed for taking small power from a high-voltage line. Fig. 7 illustrates an expansion of the idea brought out by the General Electric Company to supply 150-kv-a., three-phase from a 110-kv. line.

The Brown Boveri Company has developed an interesting high-voltage potential transformer in which the core and coils are mounted in a hollow insulating bushing between a metal top and a grounded metal

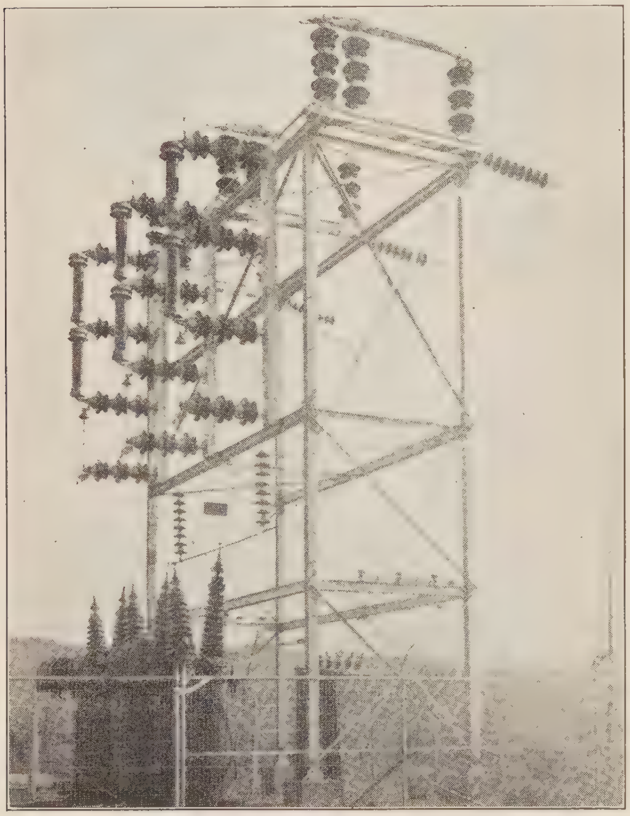


Fig. 7—150-Kv-a. 110,000-Volt Three-Phase Unit Design Outdoor Station

With type RA-1 disconnecting switch, combined fusible cut-out and current-limiting resistor, three, 50-kv-a. single-phase transformers, low-voltage switch house and steel structure. View from side of tower.

bottom tank, with the primary leads connected to the cover and bottom tank.

An interesting metering transformer combination has been supplied to the Allied Power and Light Company by the Westinghouse Company for use on a 154-kv., 60-cycle system which consists of three double secondary transformers and a three-phase open-delta connected voltage transformer. The extra current transformers

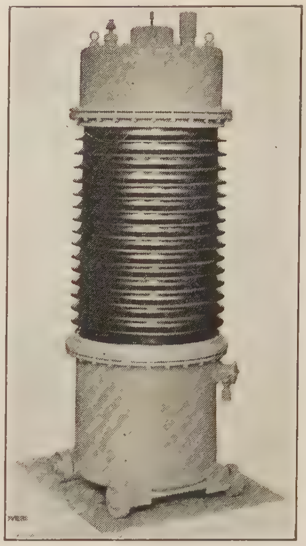


Fig. 8—150-Kv. Brown Boveri Potential Transformer with Insulation Casing

and double secondaries provide a double check and the potential transformer connection is equivalent to the use of a single-phase unit across two of the phases.

Synchronous Machinery

The increasing use of fabricated construction of rolled and welded steel members has continued and is becoming more and more universal except for standardized designs in which duplicate castings are used in large quantities. The so-called "dished" steel-plate end-shields have been applied to several large synchronous motors, hydrogen-cooled condensers, and marine motors. The General Electric Company has developed a line of bearing pedestals to harmonize with the appearance of the fabricated construction and has modified the design of the oil wells so that the rings operate completely enclosed, practically eliminating the escape of oil vapor. The bearing construction has been modified to secure more uniform distribution of the pressure.

The year 1928 saw a large increase in the kv-a. capacity of water wheel generators while the size of turbo-generators stayed about the same. The past year has seen the reverse process in which the capacity of single shaft turbo-generators has been increased to 166,666 kv-a. The interest in outdoor rotating machinery has increased and several of this type have been built or are in the process of construction. The successful experience with hydrogen-cooled condensers has been continued and more machines of this type are under construction.

Hydraulic Generators. The following is a list of some of the more interesting hydraulic driven generators installed or being built during the past year:

Purchaser	No.	Kv-a.	Speed	Manufacturer
Dnieprostroy Hydroelectric Dev.	4	77,500	88.2 r.p.m.	General Electric
Sao Paulo Tramways	1	55,000	360 "	" "
New York Power and Light Co.	1	47,000	81.8 "	" "
Aluminum Co. of America	2	45,000	150 "	Westinghouse
Carolina Power & Light Co.	3	45,000	400 "	"
Lexington Power Company	4	40,625	138 "	"
New England Power Company	4	39,000	138 "	"
City of Seattle	1	33,000	257 "	"
Arkansas Power & Light Co.	2	31,111	94.7 "	Allis Chalmers
Portland Oregon Electric Power Co.	1	30,000	514 "	General Electric
City of Tacoma	2	30,000	300 "	Allis Chalmers
Alabama Power Co.	2	29,000	100 "	Westinghouse
Central Maine Power Co.	2	26,667	138.5 "	General Electric
Montana Power Co.	2	25,000	81.8 "	Westinghouse

The 55,000-kv-a., 360-rev. per min. machine which is being built by the General Electric Company is the largest horizontal water-wheel generator which has been built up to the present time. The 47,000-kv-a., 81.8-rev. per min. generator is a vertical unit of the overhung type with the guide and thrust bearings located together beneath the rotor.

The machines for the Lexington Power Co., New England Power Co., and the Montana Power Co., built by Westinghouse are all of the over-hung type.

The 31,111-kv-a. generator being built by the Allis Chalmers Company is also the over-hung type. The stator is of welded plate and the rotor spider is made of cast steel in four segments. The poles are bolted to the spider and the arms are shrouded to reduce windage loss.

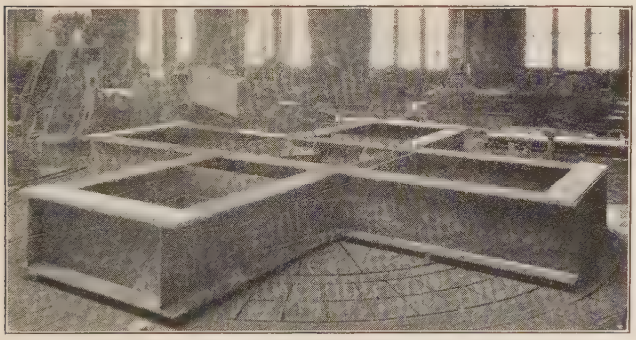


Fig. 9—Upper Bearing Bracket of 77,500-Kv-a. General Electric Water Wheel Generator for Dnieprostroy Hydro-Electric Development, Russia

The Brown Boveri Company has built a vertical 20,000 kv-a., 250-rev. per min. machine which is particularly interesting in that it is capable of supplying the same rated output at either 50 or 16⅔ cycles at the same speed. When operating to produce 50 cycles, the spider is provided with 24 poles dovetailed into one slot each and when delivering 16⅔ cycles there are 8 poles fitting two dovetails with an empty slot between each two poles.

Steam Turbine Generators. The size of single shaft units has increased until now the General Electric Company is building a 166,666-kv-a., 1800-rev. per min., single-shaft turbo-generator for the State Line Generating Company and the 160,000-kv-a., 1500-rev. per min., 25-cycle, single-shaft, turbo-generator built by the same company is operating in the East River station of the New York Edison Company. The 235,000-kv-a., three-shaft generator at the State Line Plant at Chicago was placed in operation during the year.

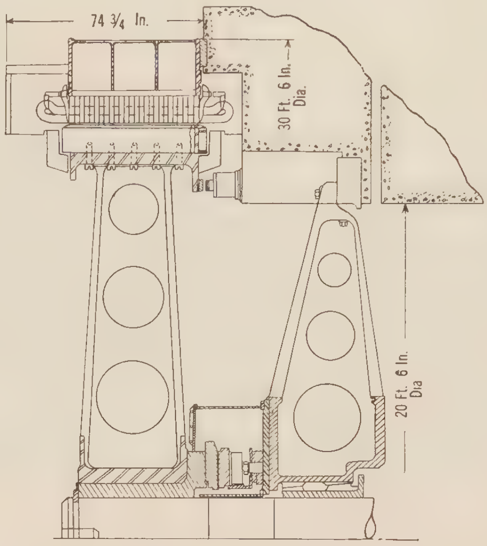


Fig. 10—Cross-Section Sketch of Allis Chalmers Co's. 31,111-Kv-a. Overhung Type Hydraulic Machine

Built for Arkansas Power & Light Company

The Allis Chalmers Company is building a 115,000-kw., 18,000-volt, 1800-rev. per min., single-shaft generator for the Waukegan Station of the Public Service Company of Northern Illinois. The rotor is a single forging and is one of the largest yet undertaken; rough-turned; the weight is 240,000 lb. On these extremely large, long generators, external motor driven fans are being used so as to keep the span between the bearings as short as possible.

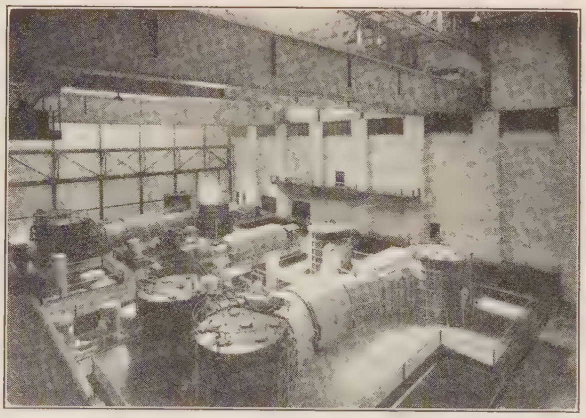


Fig. 11—235,000-Kv-a. Three-Shaft Generator

Built by the General Electric Co. for the State Line Plant of Chicago

An interesting development in turbo generators has been the vertical compound type of installation de-

veloped to reduce floor space. The largest of these is that installed at the Ford Motor Company consisting of two units, each running at 1800-rev. per min. with a total capacity of 124,911 kv-a. Two units of this type are being furnished the Pacific Gas and Electric Company by the General Electric Company in which the low pressure unit operates at 1800-rev. per min. and the high pressure at 3600-rev. per min. and with a total capacity of 50,000-kv-a. Two similar machines are being furnished the Jersey Central Power and Light Company by the General Electric Company with a total capacity of 31,250 kv-a.

The Westinghouse Company has increased the size of 3600-rev. per min. units to 18,750 kv-a. Three of these machines are being built for the Louisiana Steel Products Company and two for the Virginia Public Service Company. These generators are equipped with special propeller type fans mounted on the shaft.

The Westinghouse Company has been able to make an interesting factory test on two duplicate turbo generators of 68,800-kv-a. capacity built for the Duke Power Company. The test included a "pump-back" loading at 0.8 power factor full load and substantiated the present A. I. E. E. Standards which use the short circuit losses as equivalent to the load losses at full voltage and full load.

Voltage of 22,000 has thus far proved efficient, and there are five General Electric generators at this voltage which have been in successful operation for periods varying from several months to one and one-half years. Two 116,600-kv-a. and one 166,666-kv-a. generators are being built for 22,000 volts.

Fig. 12—240,000 Lb. Single Forging for the 115,000-Kw. Generator Rotor Being Built by the Allis Chalmers Co.

The use of the double winding generator is being extended and there are now 768,333 kv-a. of double winding generators of General Electric manufacture in operation or in the course of construction.

Synchronous Motors. The use of synchronous motors has been extended to include band saws, fans and blowers, and flour mills. The General Electric Company is now building one 3000-hp., 124-rev. per min., compressor motor which is believed to be the largest motor for this service undertaken so far. The two largest diameter synchronous motors are 25 ft. in diameter and are supplied by the Westinghouse Company to the Columbia Steel Company for driving a billet mill and a sheet bar mill. The motors are rated 5000 hp., 82 rev. per min. at 2300 volts and when started at full voltage the starting torque is 95 per cent with 330 per cent current in-rush. The torque of pull-in is 40 per cent and the pull-out is 220 per cent. The Westinghouse Company is building an 1800-hp., 150-rev. per min. motor for a piercing mill of a seamless tube plant which develops a pull-out torque at 350 per cent of normal load.

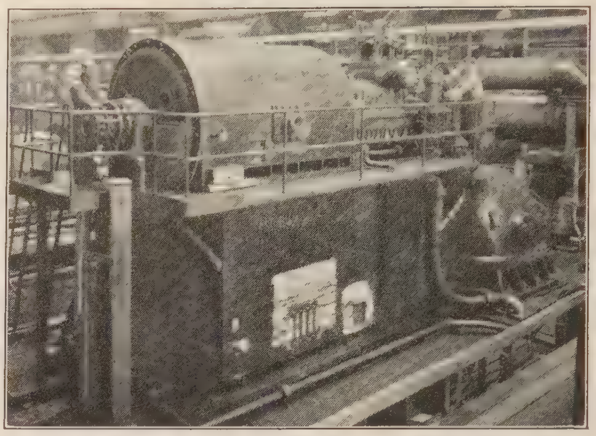


Fig. 13—25,000-Kw. General Electric Vertical Compound Steam Turbine Generator for the Jersey Central Power & Light Co., Being Assembled for Test

There seems to be an increasing demand for high speed synchronous motors and the Allis Chalmers Company has recently built a 500-hp., 3600-rev. per min. motor for driving a pump. The construction of this is similar to that of a turbo generator except for special features to provide adequate starting.

The General Electric Company has built some synchronous motors with two circuits, one of which is left open when starting, to reduce the starting current when started at full voltage.

Dynamic braking has been applied for reducing the time of stopping. Some applications have been made in which the field circuit has been connected single circuit for running and two circuits parallel for stopping, giving the equivalent of double excitation during the braking period.

The Allis Chalmers Company has built a number of synchronous induction type motors for cement mill drive which give the advantage of high starting current and moderate line current during the starting period without clutches and give the advantages of the synchronous motor under normal running condition.

Marine Synchronous Motors. During the year the *SS. Pennsylvania* joined the *SS. Virginia* and *SS.*

California in commercial operation. These 18-knot vessels are each propelled by two 8500-hp., 120-rev. per min., self-starting synchronous motors. The Grace Line *SS. Santa Clara* was launched and will be equipped with two 6300-hp., 120-rev. per

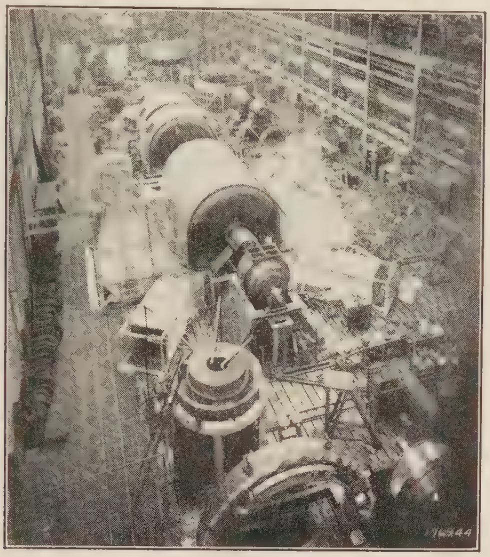


Fig. 14—View in Westinghouse Shops Showing "Pump Back" Test of Two Duplicate Generators of 68,800 Kv-a. Capacity

min., self-starting synchronous motors to drive the ship at 19 knots. Four 8000-hp., 143-rev. per min., self-starting synchronous motors were completed for the two Ward ships, *SS. Oriente* and *SS. Morro Castle.*

Fig. 15—The Largest Diameter Synchronous Motor. It Drives a Sheet Bar Mill for the Columbia Steel Co.

The above equipment was furnished by the General Electric Company. Two ships are being built for the Dollar Line which will be the largest and highest powered of any ships built in the country for commercial service with electric drive. The General Electric Company will furnish the two 13,250-hp. synchronous motors for one ship and the Westinghouse will furnish the same drive for the other.

Synchronous Condensers. The Westinghouse Electric and Manufacturing Company have on order a 15,000-kv-a., hydrogen-cooled condenser for the Indiana and Michigan Electric Company and a 15,000-kv-a., hydrogen-cooled machine for the Southern California Edison Company. The General

Fig. 16—A 500-Hp., 3600 Rev. Per Min. Synchronous Motor Built by the Allis Chalmers Co.

Electric Company is building a 15,000-kv-a., 900-rev. per min., 24,000-volt, hydrogen-cooled condenser for the American Gas and Electric Company. There are now 32,500 kv-a. in hydrogen-cooled condensers of General Electric manufacture in operation and 75,000 kv-a. in construction. The largest size condensers now under construction include a 30,000-kv-a., 600-rev. per min. machine for the Public Service Electric and Power Company of New Jersey, a 30,000-kv-a., 600-rev. per min., 60-cycle unit for the Southern California Edison Company, being

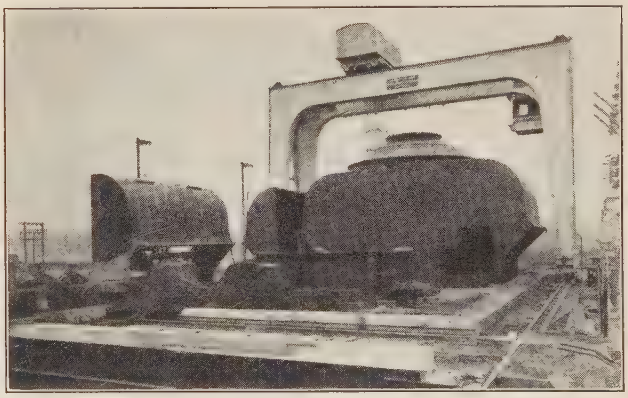


Fig. 17—The First of Two 25,000 Kv-a., 500-Rev. Per Min. Outdoor Condensers

Furnished the Toronto Leaside Station by the Canadian Westinghouse Co.

built by the General Electric Company, a 30,000-kv-a., 720-rev. per min. synchronous condenser being built by the Allis Chalmers Company, and one at 720-rev. per min. and two at 600 rev. per min. of the same capacity constructed by Westinghouse.

The Canadian Westinghouse reports the installation of two 25,000-kv-a., 500-rev. per min. vertical outdoor synchronous condensers at the Toronto Leaside transformer station of the Hydro-Electric Power Commission of Ontario. These machines are of particular interest in that they are the first vertical shaft outdoor type condensers with the exciters suspended below the thrust bearing, which is located under the rotor.

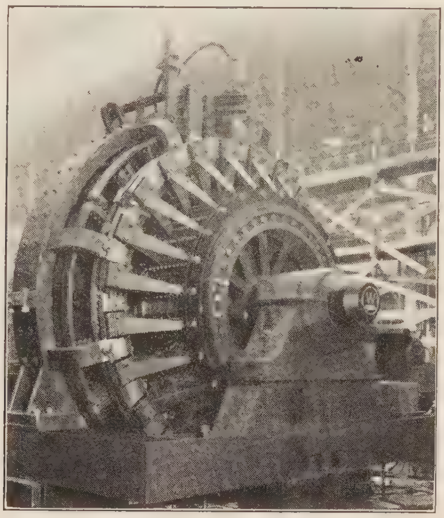


Fig. 18—3900-Kw., 13,000 Ampere Rotary Converter

Being built by Westinghouse Elec. & Mfg. Co. for Commonwealth Edison Co. of Chicago

Frequency Converters. The Westinghouse reports the installation of a second 40,000-kv-a. frequency changer of the synchronous-synchronous type for the Commonwealth Edison Company. The same manufacturer is building an 18,750-kv-a., 300-rev. per min. set for the Consumers Power Company to act as a tie-in between a 30-cycle and a 60-cycle system. It is expected that at a later date the machines may be split and each one used as a 60-cycle condenser. The 30-cycle end will then be operated with a rating of 35,000-kv-a. at 600 rev. per min.

The Toledo Edison Company has placed in operation a 35,000-kw., 300-rev. per min. General Electric synchronous-synchronous set having a 46,000-kv-a., 60-cycle, 13,500-volt motor and 41,176-kv-a., 25-cycle, 6750-volt generator.

D-C. Machines

The use of fabricated construction which has rapidly increased during the past few years has been more extensively applied to direct current machines of various sizes. The use of rolled-steel field yokes is practically universal in large sized machines.

Greater attention is being given by operating companies to ventilation of machines so as to prevent recirculation of air causing high ambient temperatures. The use of the volute housing in which the ventilation of the machine is used to force the heated air, through ducts, out of the building has been extended and the synchronous converters which the General Electric Company is constructing for the New York City Board of Transportation will be equipped with this type of ventilation.

Synchronous Converters. The largest 60-cycle converters for railway service, and the first to use 12 phase for this application, are under construction by the General Electric Company for the Board of Transportation of the City of New York. They will have a nominal rating of 4000 kw. at 625 volts with a 200 per cent rating for five minutes and 300 per cent rating for one minute. A 25-cycle converter for chemical work having a current rating of 16,000 amperes for voltages from 270 to 340 is being built. It is believed that this is the largest current rating of a synchronous converter for the extremely high load factor commonly experienced in electrolytic work, although a similar machine was built several years ago for 17,000 amperes lighting service.

An extremely interesting development is a 3000-kv-a. 60-cycle 300-volt converter being built by the General Electric Company for hydrogen cooling. This machine is to be used in a chemical plant in which the complete enclosure with hydrogen cooling serves as a protection against fumes as well as secures the greater effectiveness of cooling. No operating information has been secured at this writing.

An example of the extensive use of fabricated construction is found in some 3900-kw. booster-type 60-cycle converters being built for the Commonwealth Edison Company of Chicago by the Westinghouse Company. With the exception of the pedestals, the entire machine is made of structural steel. The rolled frame and welded type of construction in the manufacture of the bedplate, commutator, spider and brush rigging can be seen in Fig. 18. The same fabricated type of construction is being used on two 5440-kw. 25-cycle field controlled converters built by the same manufacturer for the Roessler and Hasslacher Chemical Company of Niagara Falls.

Fig. 19—D-C. Motors Driving the 12-In. Hot-Strip Mill

The six 1250-hp. motors driving finishing stands are mounted on common bedplate. 4500-hp., 150/450 rev. per min. roughing mill motor in background. The Sharon Steel Hoop Co., Sharon, Pa.

Generators and Motors. The Westinghouse is now

building a 10,000-hp. blooming-mill-drive involving a number of interesting features. The upper and lower rolls are each independently driven by a 5000-hp. motor, the pinion and pinion housing normally used to connect the upper and lower rolls being com-

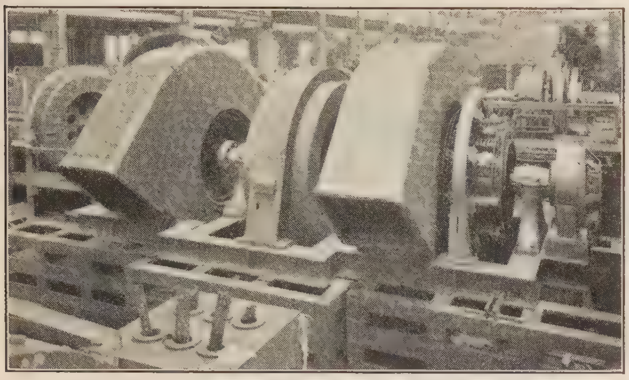


Fig. 20—A General Electric 1500-Kw. Synchronous Motor, D-C. Generator Set with Volute Ventilating Housing

pletely eliminated. The two motors are located at the same end of the mill giving improved efficiency, greater flexibility, and reduced first cost to the steel mill. The power for the drive is obtained from an induction motor-generator set having three d-c. generators operating in parallel.

The General Electric Company has built an equipment for a 12-in. hot-strip mill consisting of six 1250-hp. motors on a single base arranged on 8 ft. centers. Due to the wide range in basic speeds, from 103 to 312 rev. per min., double motors were used for three of the units.

An interesting motor-generator set has been built by the General Electric Company for the drive of a 7000-hp. and 1650-hp. reversing motor. The motor-generator set is built with three 2400-kw. generators designed to operate in parallel. Both the generators and the motors are equipped with special field windings and excitation control designed to give characteristics for a proper division of load as the five machines are connected to one bus.

Exciters. During 1929 there has been a definite trend toward providing large a-c. machines with individual exciters and a greater use of sub-exciters, that is, small exciters to provide separate excitation for the main exciters. Several large exciters for recent large turbo generators were provided with sub-exciters for mounting on the main turbine shaft. The advantages of the sub-exciter are lower losses, greater stability, and quick response.

Where it is necessary to obtain low excitation voltage from exciters feeding a-c. generators which may be required to supply charging current to long transmission lines, differential shunt fields have been employed on the exciters. These fields are about 10 per cent as heavy as the main shunt fields and are separately excited which permits the exciter to operate below its normal residual voltage value. This is especially necessary where voltage regulators are used, as the operation of the regulator depends upon its swinging the voltage beyond the average value which applies to the collector rings of the a-c. generators. By the use of the differential shunt fields the main rheostat can be entirely eliminated even when the excitation required is below that of the residual of the exciter.

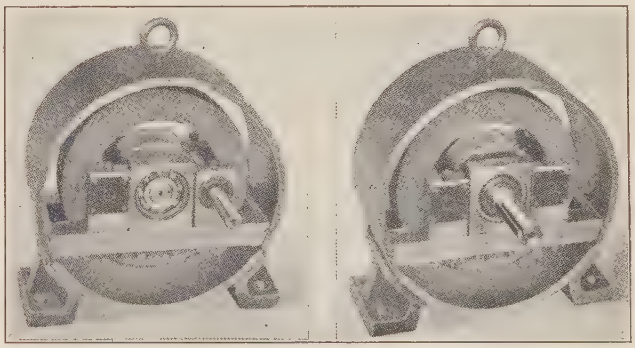
For some machines, usually synchronous condensers, it is necessary to provide excitation voltage down to zero volts. The General Electric Company obtains this condition by providing a Wheatstone Bridge arrangement in the rheostat of the separately excited main field. With this arrangement, voltages down to zero and even in a reverse direction can be obtained without resorting to special field windings on the main exciter.

Ordinary a-c. generators when used with quick response excitation require an exciter voltage change of the order of 400 to 600 volts per second. This lower value of voltage change can be obtained with exciters without the use of laminated yokes.

In a quick response excitation system where voltage required from the exciter is greater than 750 to 1000 volts per second, eddy-currents in solid frames and in thick laminations in pole pieces materially retard the rate of change of voltage. To overcome this difficulty the Westinghouse Company has designed the exciter yoke of laminations held together by insulated end plates and the pole pieces are made of thin laminations held together by insulated rivets. This construction will permit speeds of response of from 3000 to 4000 volts per second. On one synchronous condenser installation made by the General Electric Company a maximum rate of rise on the main exciter was in excess of 7000 volts per second. These extremely high speeds are used at present on synchronous condensers only and then in only rare cases.

Induction Motors

One of the most significant developments of the year is the undertaking by the various manufacturers of this



A A

Fig. 21—The Crocker Wheeler Speed Changer (Two Views)

a. "C" type reducer viewed from high-speed side with covers removed
b. "C" type reducer view from low-speed side with covers removed

country, to produce a line of motors which will comply with the standardized mounting dimensions approved

by the National Electric Manufacturers' Association. Some manufacturers are redesigning the motors electrically while dimensions are being changed. These new lines should appear on the market during the year 1930.

During the past year the developments of small induction motors has seen a more extensive application of totally enclosed motors, many of them being in the explosion-proof classification. The enclosed fan-cooled principle has been extended to larger motors; for example, the Louis Allis Company report the development of an explosion-proof self-ventilated motor which can be furnished in sizes up to 75 hp. and designed to withstand internal pressures up to 100 lb. per sq. in. The use of the enclosed fan-cooled motor is finding some application as a drive for fuel pulverizer mills. As an adjunct to the smaller line of induction motors the Crocker Wheeler Company has developed a new line of toothless speed changers which are reported to have an efficiency of 99 per cent at three-quarters load and 98½ per cent at full load.

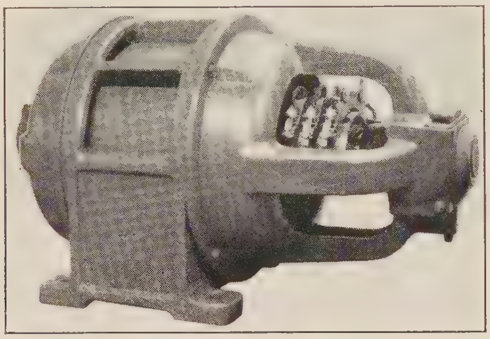


Fig. 22—Five Kw., 60/180-Cycle Single Unit Frequency Changer Eight Per Cent Regulation

The use of the capacitor motor has been extended, for some applications with the capacitor in service continuously and for others only during the starting operation. The General Electric Company has brought out single-phase capacitor motors for use in driving propeller type fans. By the use of a high resistance rotor the speed of the fan may be controlled by varying the applied voltage, as by means of taps on an autotransformer. The Electrical Machinery Company has put on the market a scheme of connecting a capacitor across the induction motor terminals during starting in order to reduce the kv-a. in-rush. After the motor is up to speed, the capacitor is disconnected from the line and is available for use in starting other motors.

For furnishing power to high speed hand tools a new type of single-unit frequency changer has been developed by the General Electric Company which is adaptable for a change of frequency from 60 to 180 cycles. It combines in a single unit the function of a frequency changer and a driving motor of the conventional two unit set. By eliminating the base, coupling, and driving motor the single unit frequency changer occupies a minimum of room.

The use of a two circuit induction motor in which only one circuit is used for starting has been developed to reduce the current in-rush during starting.

The General Electric Company has built a 27,500-hp. induction motor which is part of a 20,000-kw. induction-synchronous frequency-changer set now in operation on the system of the Buffalo General Electric Company. Two similar sets are being built for the Union Electric Light and Power Company of St. Louis. The Canadian

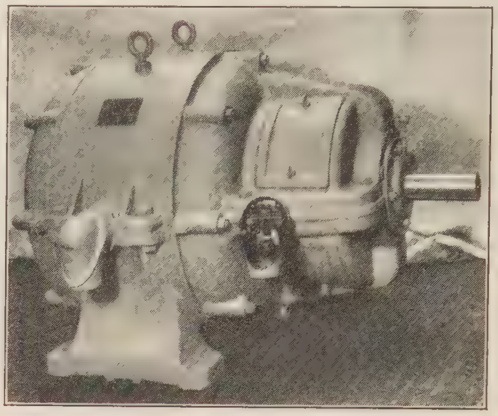


Fig. 23—Induction Motor Furnished the Welland Ship Canal by the Canadian Westinghouse Co.

The top half of the frame may be removed to replace parts

Westinghouse Company is furnishing some 200-hp. motors for the Welland Ship Canal of rather special construction illustrated in Fig. 23. The object of the design is to make it possible to lift the top half of the frame and then remove the complete electrical and mechanical parts of the lower half so that spare parts could be quickly inserted in the frame.

Progress has been made in the application of polyphase adjustable speed a-c. motors for the needs of the textile industry; as an example, one manufac-

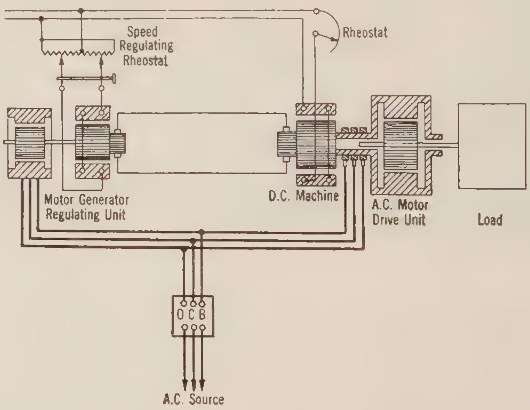


Fig. 24—Diagram of Connections

turer has received an order for 2000 such commutator type motors having shunt characteristics and rated 3-hp. at 1650 rev. per min. maximum speed. The motors are to be used for driving full-fashioned hosiery knitting mills requiring close speed regulation and adjustable speed which is readily obtained by shifting the brush position.

A new scheme of speed control has been developed by

Sargent and Lundy of Chicago, making use of an induction motor whose stator is connected rigidly to the armature of a d-c. motor and mounted on bearings so that it can be rotated. The d-c. motor may drive or be driven by a d-c. generator whose voltage is adjustable from maximum positive through zero to maximum negative so that the so-called stator may be rotated in either direction at any speed within its maximum limits. Those now in operation have been built to have a speed range of from 100 per cent to 40 per cent. The d-c. motor and generator may be only a small percentage of the total horsepower of the main motor as they supply only the difference in power required between the operating speed and synchronous speed. The capacity of the direct current machines now in operation is approximately 16 per cent of the induction motor rating.

Mercury Arc Rectifiers

Since January 1, 1929, a total of 78 mercury arc rectifiers sets with an aggregate rating of 179,900 kw.

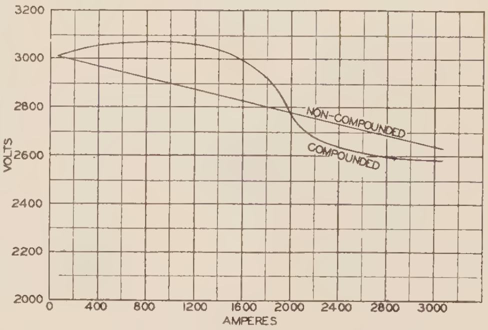


Fig. 25—Regulation Curves of Rectifiers for D. L. & W. R. R. Electrification

MERCURY ARC RECTIFIER UNITS INSTALLED OR ON ORDER IN THE UNITED STATES AND CANADA SINCE JANUARY 1, 1929

Purchaser	No. of sets	D-c. volt	Kw. per set	Total kw.	Control	Service	Put in service	Manufacturer
American Gas & Electric, New York	2	620	1,000	2,000	Automatic	Railway	1929	Brown Boveri
American Gas & Electric, New York	2	610	500	1,000	Automatic	Railway	On order	Brown Boveri
Boston Elevated Railway	2	600	3,000	6,000	Automatic remote control	City	On order	General Electric
B. C. Electric Railway	1	575	1,000	1,000	Manual	Urban	1929	General Electric
Calgary, City of	1	575	600	600	Automatic	Railway portable	1929	Brown Boveri
Calgary, City of	1	575	1,200	1,200	Automatic	Railway	1929	Brown Boveri
Chicago & Joliet Electric Railway Co	1	620	1,000	1,000	Automatic	Interurban	1929	General Electric
Chile Exploration Co	1	650	1,000	1,000	Automatic	Heavy mine haulage	On order	General Electric
Columbus Railway Power & Light Co	1	600	500	500	Automatic	Urban	1929	General Electric
Columbus Railway Power & Light Co	1	600	500	500	Automatic remote control	Urban	1929	General Electric
Commonwealth Edison Co	1	1,500	1,500	1,500	Manual	Railway	Being erected	Brown Boveri
Commonwealth Edison Co	2	600	3,000	6,000	Automatic	Railway	1929	Brown Boveri
Commonwealth Edison Co	4	625	3,000	12,000	Manual	Railway	Being erected	Brown Boveri
Commonwealth Edison Co	1	1,500	1,500	1,500	Manual	Railway	Being erected	Brown Boveri
Commonwealth Edison Co	3	625	3,000	9,000	Manual	Railway	On order	Brown Boveri
Commonwealth Edison Co	3	625	3,125	9,375	Manual	Urban	On order	General Electric
Consolidated Mining & Smelting Co. of Canada	3	460/560	5,600	16,800	Manual	Electrolytic	1929	Brown Boveri
Consolidated Mining & Smelting Co. of Canada	2	650	6,500	13,000	Manual	Electrolytic	On order	Brown Boveri
Consolidated Mining & Smelting Co. of Canada	1	650	6,500	6,500	Manual	Electrolytic	On order	General Electric
Delaware, Lackawanna & Western Railroad	11*	3,000	3,000	33,000*	Manual	Railroad electrification	On order	General Electric
Delaware, Lackawanna & Western Railroad	2	3,000	2,000	4,000	Automatic remote control	Railroad electrification	On order	General Electric
Eastern Massachusetts Street Railway Co	3	600	1,000	3,000	Manual	Urban	1929	General Electric
Edmonton, City of	1	575	1,325	1,325	Manual	Railway	1929	Brown Boveri
Ford Motor Co	2	460	1,000	2,000	Manual	Power	On order	Brown Boveri
Halifax Tramways	1	590	1,100	1,100	Manual	Railway	1929	Brown Boveri
Municipality of Milan (Italian G. E.)	1	550	1,000	1,000	Manual	Urban	1929	General Electric
Montreal Tramways Co	1	600	2,400	2,400	Automatic	Railway	1929	Brown Boveri
Montreal Tramways Co	2	600	1,500	3,000	Automatic remote control	Urban	Under installation	General Electric
Philadelphia, City of	2	630	2,500	5,000	Manual	Subway	Being erected	Brown Boveri
Piedmont & Northern Railway	4	1,500	750	3,000	Automatic remote control	Railroad electrification	1929	General Electric
Public Service Co. of No. Ill., Chicago	1	600	1,900	1,900	Manual	Railway	On order	Brown Boveri
Public Service Co. of No. Ill., Chicago	1	600	1,900	1,900	Automatic	Railway	On order	Brown Boveri
Public Service Co. of No. Ill., Chicago	1	1,500	1,500	1,500	Manual	Railroad electrification	1929	General Electric
Sacramento Northern Railway	1	1,500	500	500	Automatic	Interurban	1929	General Electric
Saskatoon, City of	1	575	600	600	Automatic	Railway	1930	Brown Boveri
Toronto Hydro Electric System	2	600	1,100	2,200	Automatic	Railway	1929	Brown Boveri
Union Railway Co. of New York City	1	625	1,000	1,000	Automatic	Railway	1929	Brown Boveri
City Subways of New York	7	625	3,000	21,000	Automatic remote control	Railway	On order	General Electric
Totals	78*			179,900				

*In addition one spare 3000-kw. rectifier tank (without transformer) is on order. Four of the above sets consist each of two 1500-kw. tanks operating as a unit.

MERCURY ARC RECTIFIER UNITS INSTALLED IN THE UNITED STATES AND CANADA PRIOR TO JANUARY 1, 1929

Purchaser	No. of sets	D. c. volt	Kw. per set	Total kw.	Control	Service	Put in service	Manufacturer
American Gas & Electric, New York....	1	575	300	300	Automatic	Railway	1927	Brown Boveri
Calgary, City of, Canada...............	1	575	600	600	Semi-automatic	Railway	1928	Brown Boveri
Canadian National Railways, Montreal..	1	600	1,200	1,200	Manual	Railway	1928	Brown Boveri
Chicago, North Shore & Milwaukee R. R.	1	600	1,000	1,000	Automatic remote control	Interurban	1926	General Electric
Chicago & Joliet Elec. Ry. Co..........	1	600	500	500	Automatic	Interurban	1928	General Electric
Columbus Railway Power & Light Co....	1	600	1,000	1,000	Manual	Urban	1927	General Electric
Columbus Railway Power & Light Co...	1	603	1,000	1,000	Manual	Railway	1927	Brown Boveri
Commonwealth Edison Co., Chicago.....	1	621	600	600	Manual	Railway	1925	Brown Boveri
Commonwealth Edison Co., Chicago.....	1	621	1,200	1,200	Manual	Railway	1925	Brown Boveri
Commonwealth Edison Co., Chicago.....	2	1,500	3,000	6,000	Manual	Railway	1926	Brown Boveri
Commonwealth Edison Co., Chicago.....	1	1,500	1,500	1,500	Manual	Railroad electrification	1926	General Electric
Connecticut Co., New Haven...........	5	600	1,200	6,000	Manual	Railway	1927	Brown Boveri
Connecticut Co., New Haven...........	2	600	1,200	2,400	Automatic	Railway	1927	Brown Boveri
Delaware, Lackawanna & Western R. R.	1	600	200	200	Semi-automatic	Railway	1926	Brown Boveri
Dominion Power & Transmission Co., Montreal.........................	1	600	600	600	Automatic	Railway	1928	Brown Boveri
Duquesne Light Co.....................	2	600	1,000	2,000	Manual	Urban	1927	General Electric
Ford Motor Co., Detroit...............	1	250	550	550	Manual	Power	1925	Brown Boveri
Gary Railways Co., Gary, Indiana.......	1	600	500	500	Automatic	Railway	1926	Brown Boveri
Lethbridge, City of, Canada............	1	500	400	400	Manual	Railway	1927	Brown Boveri
Long Island R. R., New York...........	1	650	1,000	1,000	Semi-automatic	Railway	1926	Brown Boveri
Long Island R. R., New York...........	3	650	1,000	3,000	Automatic remote control	Railroad electrification	1928	General Electric
Los Angeles Railway Corp..............	2	600	500	1,000	Automatic	Urban	1928	General Electric
Milwaukee Electric Railway & Light Co.	3	600	550	1,650	Automatic	Railway	1927	Brown Boveri
Montreal Tramways Co................	2	600	1,200	2,400	Automatic	Railway	1927	Brown Boveri
Montreal Tramways Co................	1	600	1,200	1,200	Automatic	Railway	1928	Brown Boveri
H. Morgan & Co., Montreal, Canada....	2	265	132	264	Manual	Power	1928	Brown Boveri
New York Edison Co..................	1	240/260	570	570	Manual	Power	1925	Brown Boveri
Northern Indiana Public Service Co.....	1	1,500	1,500	1,500	Automatic remote control	Interurban	1926	General Electric
Northern Indiana Public Service Co.....	3	1,500	750	2,250	Automatic remote control	Interurban	1926	General Electric
Northern Indiana Public Service Co.....	2	1,500	750	1,500	Automatic remote control	Interurban	1928	General Electric
North Shore Power Co., Montreal.......	1	600	600	600	Manual	Railway	1927	Brown Boveri
Philadelphia Rapid Transit Co..........	2	600	500	1,000	Automatic	Urban	1927	General Electric
Philadelphia Rapid Transit Co..........	3	600	1,000	3,000	Automatic	Urban	1928	General Electric
Portland Electric Power Co............	2	1,350	750	1,500	Manual	Interurban	1927	General Electric
Public Service Co. of Northern Illinois...	1	1,500	1,500	1,500	Manual	Railroad electrification	1927	General Electric
Southern Public Utilities Co............	1	600	750	750	Manual	Railway	1928	Brown Boveri
United Traction.......................	1	600	500	500	Automatic	Urban	1924	General Electric
Utilities Power & Light Co., Chicago....	1	600	550	550	Manual	Railway	1927	Brown Boveri
Utilities Power & Light Co., Chicago....	1	600	900	900	Manual	Railway	1927	Brown Boveri
Totals.........................	60			54,184				

have been put in operation or on order in the United States and Canada. The largest part of this equipment has placed an order with the General Electric for seven 3000-kw. rectifiers which will be used in single unit is for railway service, but some will be used for other applications; for example, four large units each having a rating of 10,000 amperes at 650 volts are now on order for electrolytic use.

Two new features of particular interest have been developed by the General Electric Company and will be applied for the first time to rectifiers which are being constructed for the Delaware, Lackawanna and Western Railroad. These consist of a biased grid adjacent to the anodes which deionizes the vapor as the current passes through zero and materially reduces the tendency to arc-back; and compounding features, using static condensers in the compounding circuit, which give substantially flat compounding up to 150 per cent load, and incidentally materially improve the power factor of the rectifier unit. The biased grid consists of a grid located directly below the anode connected to a cylindrical insulated shield surrounding the anode. The shield and grid are energized from an auxiliary transformer in such a manner as to supply the grid with a potential of the desired phase relation to the anode potential. The grid thus installed acts to deionize the vapor in the

FIG. 26—THREE 5600-KW. RECTIFIER SETS (BROWN BOVERI) FOR CONSOLIDATED MINING & SMELTING CO. AT TRAIL, B. C.

vicinity of the anode each time the anode voltage decreases to zero before the anode voltage can reach a negative value.

The General Electric Company reports continued success with the use of the graphite anode and has standardized on such anodes for all rectifiers. The General Electric Company has also standardized on the Mycalex Anode Seal in place of the porcelain mercury seal. On the other hand the Brown Boveri Company continues the use of metal anode for all classes of rectifiers.

The Delaware, Lackawanna and Western will use rectifiers exclusively for conversion units for its suburban electrification. Thirteen 3000-volt rectifier units with an aggregate capacity of 37,000 kw. and one spare 3000-kw. rectifier tank are now on order. These units will have a rating of 150 per cent for two hours and

Fig. 27—Three 1000-Kw., 600-Volt General Electric Rectifiers

Arranged for operation on either 25- or 60-cycle supply, installed in the Fall River substation of the Eastern Mass. Street Railway Co.

300 per cent rating for five minutes and on tests have been carried far beyond these limits.

A portable substation equipped with a 600-kilowatt 575-volt rectifier unit by Brown Boveri has been completed and put in service in 1929 by the Electric Light and Power Department of the City of Calgary.

The Board of Transportation of the City of New York stations to supply the new subway system. While part of the supply for the subway system will be from multiple-unit synchronous converter substations, one section of the initial line will be operated from these single-unit stations which will be installed underground, adjacent to the subway tunnel.

In Europe a 400-kw. 12,000-volt rectifier has been successful in radio transmission work and several similar high-voltage sets are now on order. Rectifiers for 2125 kilowatts 465 to 475 volts have been supplied to steel mill operation. These units were designed and built by Brown Boveri, Inc. The attached tabulation indicates the rapid growth of this type of converting equipment.

APPLICATIONS TO MINING WORK*

To the Board of Directors:

In the report made one year ago mention was made of the prediction that both coal and metal mining are entering a new era of development. This has begun and indications point to a continuance of development particularly as to mechanization. We now have references made to some modern mines as being 100 per cent mechanized. Future developments will no doubt modify the scheme of application of mechanical operation in many details. Statistics indicate that an increasing percentage of coal is undercut, drilled, and loaded mechanically. This means that added generating capacity and conductors for distribution will be required. Also, inasmuch as power purchased from the utilities is increasing in use at the mines, the mechanization adds to the utility load.

Pumps

One company[1] installed ten synchronous motor-driven mine pumps from 300 to 600 hp.

Motor Generator Sets

With increasing mechanization more power at the face is required. This has been accomplished in many cases by sets near the face. These are usually controlled by automatic switchboards, which have been simplified by the majority of manufacturers.

Some installations of portable substations have been made.[2] These are adaptable to installations where conditions of loading change rapidly.

Some installations of mercury arc rectifiers have been made, rated 300 kw. at 275 volts.[3]

Shovels

The largest shovel made to date was placed in operation this past year.[4] It has a 15-yd. dipper on 120-ft. boom, weighing 1800 tons with an aggregate of some 5500 hp. in equipment, consisting of 700-kv-a. synchronous motor on multiple mg. set and main hoist operated by two 450-hp. motors, with a number of smaller motors, all handled by Ward Leonard control.

Smaller electric shovels from two to eight yard capacity are rapidly displacing steam shovels in the metal mines, 22 having been purchased by one company since January 1929.

In connection with electric shovels, as well as with other portable equipment, the trailing cables are im-

*COMMITTEE ON APPLICATIONS TO MINING WORK:

Carl Lee, Chairman,

A. R. Anderson,	E. J. Gealy,	D. E. Renshaw,
Graham Bright,	L. C. Ilsley,	W. F. Schwedes,
John H. Edwards,	J. E. Kearns,	F. L. Stone,
Frank E. Fisher,	W. H. Lesser,	J. F. Wiggert.
	S. O. Miller,	

1. Susquehanna Collieries Co.
2. Butler Consolidated Coal Co. Furnished by G. E. Co.
3. Glen Alden Coal Co. Equipment by G. E. Co.
4. United Electric Coal Co. Equipment by G. E. Co. and Marion.

Presented at the Summer Convention of the A. I. E. E., Toronto, Ont., Canada, June 23-27, 1930. Printed complete herein.

portant. The art of field vulcanizing is being perfected rapidly to take care of break-downs.

Slushers

Motor-driven double-drum slushers generally driven by a 15-hp., 3-phase, 440-volt motor, have become a part of the metal miner's equipment.

Mining Machines

Track-mounted cutting machines have found a general use in mechanized coal mines. With such a machine about twice the work per day can be performed as is possible with the shortwall type of mining machine.

Loading Machines

In coal mining there has been some increase in the use of pit-car loaders, where low ceiling and bad roof prevail. However, where conditions permit, the full mechanical loaders have gained in favor. Statistics are not complete, but indications are that some 500 or more units of this type are now in service. There have been many experimental loaders tried out, and there are more now in the process of design and manufacture. The principal problem is one of a mechanical nature, though nearly all designs involve the use of electric drive.

Welding

The mines have been using both electric and gas welding to an increasing advantage. This has been applied to repair work more than to construction work.

Safety Work

The Bureau of Mines has continued to expand its field of work.[5] In 1929 there were 19 approvals, 760 extensions granted and 31 manufacturers holding approvals on "Permissible" motor driven equipment.

The Industrial Commission of Utah has passed Resolution No. 950, providing that nothing except "Permissible" equipment may be used in gaseous mines after Jan. 1, 1932. This will necessitate a considerable amount of new equipment.

One company has displaced electric motors for jigging conveyors at the face and is now using air engines. Another has installed air motors on arc wall cutting machines, instead of electric motors. In both instances this was for safety.

Agitation continues for better lighting. In the metal mines this has been met to some extent by installing 440-volt/110-volt dry type transformers and portable lamps at or near a-c. motor-driven slushers.

Many explosions have been started by temporary stoppage of air circulation. This year there has been developed a co-related system of relays, signals,[6] etc., which can be applied to mine ventilation doors, air currents and electrical circuits to perform several functions such as operating a signal, making a graphic record, sounding an alarm, shutting off inside power, etc. This system applied to a gaseous mine would be of material value in avoiding explosion hazards.

5. See Bureau of Mines Circulars 6997 and 7061.
6. See *Coal Age*, Feb. 1930, p. 89.

PRODUCTION AND APPLICATION OF LIGHT*

To the Board of Directors:

Production of Light

Statistics on Incandescent Lamp Sales.[1] The sale of large tungsten filament lamps (as distinguished from the miniature types) totaled 344,000,000 during 1929, an increase of 8.7 per cent over the previous year's sales. The fact that the production of large tungsten filament lamps alone is running well over a million lamps per working day will give some impression of the extent to which our modern life has become dependent upon this source of artificial illumination.

For these lamps the average watts per lamp in 1929 ran 60.7 as compared with 51.5 in 1919, and the average lumens per watt were 13.1 as compared with 10.5 ten years previously.

In the 100-130-volt range half of the incandescent lamps sold (49.5 per cent) were of 115 volts, 39.4 per cent were of 120 volts, 6.5 per cent were of 110 volts, and 3.4 per cent were of 125 volts, these four voltages accounting for 98.8 per cent of the total. Lamps for 220-260 volt service totaled in quantity 3.3 per cent of that supplied for the lower standard voltage range. These facts should be of special interest to electrical engineers as indicative of the trend of voltage standardization.

The Service Voltage Standardization Committee of the Apparatus Committee of the National Electric Light Association recommended some years ago as standard practise the selection of such a service line voltage as will supply the proper average voltage to 115-volt lamps, with recognized departures in the case of 110-volt systems and existing 120-volt systems. As there is commonly at least two or three volts drop in the interior wiring the voltage delivered at the customers' service switch should be correspondingly higher in order to supply an average voltage at the socket corresponding to the standard voltage of lamp selected for use.

*COMMITTEE ON PRODUCTION AND APPLICATION OF LIGHT:

Mr. G. S. Merrill, Chairman,
Mr. H. S. Broadbent, Secretary,

Prof. J. W. Barker,	Mr. L. A. Hawkins,	Mr. P. S. Millar,
Mr. W. T. Blackwell,	Prof. H. H. Higbie,	Prof. W. T. Ryan,
Prof. J. M. Bryant,	Mr. W. C. Kalb,	Mr. B. E. Shackelford,
Mr. W. T. Dempsey,	Prof. C. L. Kinsloe,	Mr. C. J. Stahl,
Mr. E. E. Dorting,	Mr. R. D. Mailey,	Mr. G. H. Stickney.

1. The Lamp Committee of the National Electric Light Association presents each year to that association a report in which the statistics relating to incandescent lamp production are analyzed in detail, and in which important developments in the production and application of light are reviewed. It is impossible to deal with this subject without covering much of the same ground. However, the statistics presented and the features of the past year's progress commented upon in this report are believed to be of particular interest to the electrical engineering profession. Those who wish more detailed statistics, as well as those who are concerned with the commercial and engineering problems of lighting, will find valuable the reports of various committees of the National Electric Light Association and the Illuminating Engineering Society.

Presented at the Summer Convention of the A. I. E. E., Toronto, Ont., Canada, June 23-27, 1930. Printed complete herein.

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Sources of Ultra-Violet Radiation. Within the past year there has been a marked advance in the production and home use of ultra-violet for artificial sunshine. The American public has shown a great interest in this development.

In a paper, *Simulating Sunlight—A New Era of Artificial Lighting,* presented at the Winter Convention, Dr. M. Luckiesh described a new tungsten-mercury arc lamp made in a bulb of special glass which transmits the short wave radiation desired. This lamp has been developed to provide a simple source of artificial sunlight having the same general form as that of an incandescent lamp. The lamp operates on low voltage, and must be used with a transformer designed with a special shape of drooping characteristic curve. A tungsten filament is placed in parallel with the arc. The filament lights first, and almost instantly some of the mercury in a small globule free in the bulb becomes vaporized and the mercury arc is formed between the tungsten electrodes. The initial starting voltage applied to the filament then drops to the normal operating value.

The carbon arc lamp has during the past year been developed to a high degree of efficiency for the reproduction of sunlight in the home. The use of cerium-cored carbons, for example, with a carefully designed chromium-plated reflector, enables it to give a close reproduction of natural sunlight throughout the ultra-violet, visible and infra-red zones. Filters of special glass can be used to cut out the very short ultra-violet radiation and transmit only that part found in natural sunshine. A limited burning period provides an important safety feature.

Other Lamp Developments. The use of larger screens in the projection of motion pictures and the probability of the perfection, in the near future, of methods for stereoscopic projection, have created a demand for a source of light of greater brilliancy than any now in use. This demand has been met by the development of a super high-intensity projector carbon. Operated at a current of 225 to 250 amperes, this carbon arc possesses an intrinsic brilliancy 50 per cent greater than the sun at zenith.

The use of gaseous conductor lamps has continued to increase during the year, and developments in the field of the hot-cathode neon lamp and in a type of lamp which produces in a single tube a light which appears subjectively white are reported in progress.

Utilization of Light

Color Lighting. Important developments have been made during the year with regard to the production of color-lighting effects in conjunction with which several systems for controlling the voltage of large blocks of power supplied to incandescent lamps have been employed. In this field the Selsyn-Thyratron Control system, used in the Chicago Opera House, and the system installed at the Barcelona Exposition (as described by Mr. C. J. Stahl in an Illumination Item in the A. I. E. E. Jl., December, 1929, p. 918) may be mentioned particularly. A device known as the "Lumitone" has also been developed to provide for manual or automatic control of color lighting circuits. These systems of control have placed at the disposal of the illuminating engineers more efficient and effective tools with which to work and will help further to popularize color lighting.

In this connection a simple yet effective application of controlled color lighting has made its appearance in the form of the Colorama, first used in the Ballroom of the St. George Hotel in Brooklyn.[2] The room is finished in flat white, and the money that would otherwise have been spent for the usual sort of wall and ceiling decoration has been put into an elaborate system of concealed color lighting by which patterns of colored light in never-ending variety are thrown on walls and ceilings. Another form of interior color lighting has been used effectively in the Sherman Hotel, Chicago.

Modernistic Note in Lighting. Modernistic lighting, referred to in the report last year, has continued to grow rapidly in favor, particularly in lobbies, entrances for office buildings, and commercial establishments visited by the public. The movement is being reflected somewhat in residential lighting equipment.

Lighting for Aviation. This subject was dealt with at length in last year's report. The incandescent lamp is used extensively in this field where the ease with which it lends itself to remote control and to operation by inexperienced personnel are important factors. The number of lighted airports has jumped from about 75 to over 300 during 1929. There has been a considerable improvement in the design of field lighting equipment as well as an extension in the application of light in actual aerial navigation.

An important contribution to the solution of the problem of night illumination of airports has been made through the use of a carbon arc searchlight equipped with a lens throwing a flat beam of wide horizontal distribution. This "pancake" of light provides good ground illumination over a radius of more than 5000 ft. The point source of light permits the use of a shadow band or path, which can be controlled from the operating tower, to protect the eyes of the aviator from glare while landing.

A method of tapping high-tension transmission lines for small amounts of power has been developed which is of interest in marking them with light in the vicinity of air ways and airports. In this system, capacitors made up somewhat similar in form and appearance to ordinary type high-tension insulators, are used. A series of these capacitors, their number depending upon the voltage of the line, is supported from the tower and the terminal on the lowest capacitor is connected to the line, while the terminal at the top is connected in series with the lighting unit to ground.

2. See "Decorating with Light," *The American Architect,* Feb. 1930, p. 26; "Decorative Color Lighting," by A. T. North, *Architectural Forum,* Feb. 1930, p. 288.

Silent Carbon Arc. The perfection of a method for silencing the carbon arc by filtering out the commutator ripple has placed it in a position where it can be used in the production of sound motion pictures, from which field it had been temporarily barred. A high capacity electrolytic condenser is connected from a point between the auxilliery and series field windings to the opposite terminal of the d-c. generator. Oscillograph tests show that the commutator ripple and consequent arc noise are effectively eliminated by this means.

Other Applications. A possible application of underwater lighting, described in the annual report last year, may be found in outlining seaplane base landing areas with light. The lighting of football fields and race tracks is becoming increasingly popular and is now fairly well standardized, increasing the recreational opportunities afforded to the public. The popularity of such night sports is indicated by the increased attendance as compared with that at similar contests held during the day; night attendance has been reported to run from two to ten times the usual day figure. Baseball is now being added to the list of night-lighted sports.

Present Saturation in Lighting

A subject of basic interest to the electrical industry was dealt with at a meeting of the New York Section of the A. I. E. E.[3] under the title of *How Much Light.* The results of a careful study made by an informal committee organized at the instance of the New York Section, "to set up an approximate estimate of the present percentage saturation of the United States in artificial light," were presented. It was estimated that the present annual consumption of 20 billion kw-hr. for lighting would have to be increased to approximately 151 billion to provide the level of illumination of probable greatest economic advantage. The present saturation in artificial light as compared with the desirable value, based solely on eye considerations, was estimated to be about 3 per cent. The room for growth in the field of electric lighting, in spite of all the progress that has been made in the last quarter century, is still very great. Physical limitations, particularly in the distribution of energy, must be removed or overcome before the electric lighting field can develop as freely and rapidly as it should, and this is a problem of particular interest to the electrical engineer.

Operating Voltage in Relation to Lighting

Voltage Conditions on Lighting Circuits. The past year has seen a general and rather surprised awakening, on the part of the electrical industry engaged in furnishing electrical energy and equipment for lighting, to the fact that the ever-increasing demands for electric light and electric service have in many cases thrown such heavy loads on existing circuits that the voltage delivered at the point of utilization during the hours of greatest use is considerably below the presumed nominal value for which the devices have been designed to operate. When the voltage at the socket is less than this normal value the customer spends less for energy to operate the lamps and for lamp renewals, but he gets so much less light in return for his reduced expenditure that the unit cost is increased and, of course, the illumination he receives from each unit is also diminished, as one per cent reduction in voltage reduces the light output about 3.4 per cent.

The problem of delivering electrical energy at the proper voltage to the point of utilization is worthy of the electrical engineer's most careful study. He should first of all have a clear comprehension of the effect of voltage variations on the wattage consumption, light output, operating cost and unit cost of light production with incandescent lamps as this is essential to the proper treatment of the problem of the economic production of light. It is rather difficult to visualize the relations of the several elements involved in this problem, especially when the effect of wiring losses and fixed charges on the wiring are taken into account (as they should be). On this account an animated form of voltage demonstration chart has been devised as a means of presenting these data.

The subject has been discussed at length from the point of view of the central station in the 1930 report of the N. E. L. A. Lamp Committee, in which the results of an extended survey of socket voltages are given.

The Mean-Voltage Meter. A device for measuring average voltage, described in an Illumination Item in the A. I. E. E. Jl., May, 1929, p. 397, has been redesigned and is now produced in a more compact form. One element is virtually a watt-hour meter with two potential coils instead of a voltage and current coil so that it registers volts squared times hours in place of watt hours. The other element is a telechron which gives the time reading so that the average voltage (root mean square) can be easily obtained. It is designed for use on 60-cycle current, 100-130 volts. This device, plugged in at the lamp socket, records only when the lamp is in operation so that it shows the average voltage delivered to the lamp during the time it was in operation. It should find extensive use in making surveys for the purpose of correcting the undervoltage operation of lamps and other electrical devices. Where recording meters are used for obtaining average socket voltage they should also be plugged in at the lamp terminal so as to register only when the lamp is burning. Voltage at other time does not affect the lamp.

Interior Wiring

Installation Standards. The problem of maintaining the proper average voltage at the socket also involves

3. See A.I.E.E. Jl., Vol. 49, January 1930, p. 70. The report was submitted to the meeting by Frank W. Smith, Chairman of the Lamp Committee of the N. E. L. A., Arthur E. Allen, Vice-President, Westinghouse Lamp Co. and Dr. E. E. Free, Consulting Engineer.

the question of the voltage drop in the wiring on the customer's premises. In last year's report reference was made to the preparation of a set of model specification paragraphs dealing with the adequacy of wiring. The Commercial and Industrial Lighting Committee of the N. E. L. A., with the collaboration of other branches of the industry and with other authorities interested in this subject, has prepared and recently issued a minimum specification for the adequate wiring of lighting circuits in commercial and public structures. Every electrical engineer who is brought into contact with the design or operation of lighting installations should be familiar with these specifications.

In this connection the wiring of the Chrysler Building described in two articles, "Wiring the World's Tallest Building," by David M. Goe, and "Chrysler Building Feeder Design," by L. Mackler, both appearing in *Electrical Contracting*, March, 1930, is well worth careful study because it represents advanced practise and refinement in design. Primary current is carried at 13,800 volts to the basement, the 30th, 60th and 72nd floors where secondary switch boards are located. The first article considers the average individual occupant in relation to his electrical requirements, floor area basis for circuiting, flexibility, facts rather than assumptions, adequacy, standardized feeder lengths, and provisions for the future. The second article describes in detail the calculations and recheck made to insure adequacy and adherence to voltage drop requirements. All this is very important from the standpoint of the application of light for it is not uncommon to find lamps operating at a voltage five or more volts below their labeled values in commercial buildings and probably rather more than this in industrial plants (extreme cases running as low as 80 per cent have been found). This undervoltage burning diminishes the light output more than it does the operating cost and results in inefficient and unsatisfactory lighting service.

Miscellaneous

Photoelectric cells are finding use in conjunction with the control of lighting installations. Electric signs, ordinarily operated by time clock alone, can have the photoelectric cell control added so that the sign will be lighted during exceptionally dark periods of the day during which it would ordinarily be unlighted. Many other applications will in all probability be found as the equipment is further developed.

A new system of interchanging lighting information among lighting engineers through the medium of data sheets describing outstanding installations has been inaugurated by the I. E. S. Committee on Lighting Service.

The accepted specifications for motor vehicle headlights have been revised by the I. E. S. Committee to include the dual-beam type of equipment, a revision of the tail-light specification is practically complete, and a new signal light specification has been drawn up.

The celebration in this country of Light's Golden Jubilee officially opened with elaborate lighting effects and special ceremonies, at the time of the National Electric Light Association Convention in Atlantic City last June. Wide-spread interest and enthusiasm lead up to the grand climax at Mr. Ford's dinner on October 21st, at which Mr. Edison completed a model of his early lamp in his old laboratory reconstructed by Mr. Ford at Dearborn.

The proceedings of the meeting of the International Commission on Illumination held in September, 1928, have been issued during the past year. The U. S. National Committee of the I. C. I. has been actively interested in the preparations which are being made for the meeting to be held next year in England. It has been especially concerned with the subject of lighting in air navigation, the movement for a better international understanding with regard to standards of light, and the dissemination of information regarding the Jubilee of Electric Light, celebrated last year in many countries.

In practically every field of service electric light is continuing to expand in usefulness, but for the most part, as pointed out above, the developments during the past year have not been of a striking nature. Only by looking back over a period of several years can the fact that steady but slow progress is being made in this field or that one be determined. Even though, in this report, no specific comment to such progress in many important fields has been made, the fact that it is being made should not be forgotten.

INSTRUMENTS AND MEASUREMENTS*

Measurement of Core Losses in Terms of Sine-Wave Core Losses

Last year, the Committee outlined three suitable methods for correcting results of core loss measurement to a sine-wave basis when made with a distorted wave of applied voltage, and for such correction recommended preference for methods utilizing average voltage. (See Annual Report, Committee on Instruments and Measurements, A. I. E. E. Trans., Vol. 48, Oct. 1929, p. 1386).

Following this recommended preference, the Committee has recommended that a method based on the measurement of average voltage be used for correcting core loss results to a sine-wave basis when made with a distorted wave of applied voltage. This action has been regularly transmitted to the transformer sub-

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Perry A. Borden,	W. N. Goodwin,	F. A. Laws,
W. M. Bradshaw,	F. C. Holtz,	R. T. Pierce,
H. B. Brooks,	J. A. Johnson,	G. A. Sawin,
A. L. Cook,	I. F. Kinnard,	R. W. Sorensen,
E. D. Doyle,	A. E. Knowlton,	H. M. Turner.

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committee of the Committee on Electrical Machinery, and to the Standards Committee.

Method of Measuring Distortion Factor

Last year the Committee defined "distortion factor" of a voltage wave and suggested several methods of measurement. Of these, the use of the Belfils Bridge seemed to be the most promising, though it was recognized that further study and development of the apparatus was necessary. (See Annual Report, Committee on Instruments and Measurements, A. I. E. E. Quarterly TRANS., Oct. 1929, Vol. 48, p. 1386.)

This year, the Committee reports that a Belfils Bridge has been built and is being used for further study of distortion factor in electrical rotating machinery.

A "dynamometer method" for measuring distortion factor has been suggested, but upon investigation it was found that this method belonged in previous Classification D covering "harmonic analyzers."

Dielectric Power Loss and Power Factor Measurements

During the past year, there has been relatively little advance made in the development of new apparatus or new methods for the determination of dielectric loss and power factor. The various people interested in these measurements have concentrated on making their apparatus more workable, the changes made in technique and apparatus being of a very minor nature.

One interesting application is that of the phase defect compensation method to the three-phase measurement of dielectric power loss and power factor.

Work is being continued on the development of high-capacitance standards for use in checking equipments designed for measurement on full reels of cable. Work on these standards is under way at the present time and it is hoped to develop a capacitor having a capacitance of 0.1 μ f. for use on voltages as high as 45 kv. It is hoped that the capacitor will have a power factor of approximately 0.0025, and will be unaffected by temperature or other operating conditions.

High-Frequency Measurements

The subcommittee has prepared a partial list of measurement papers appearing in 1929. This is given in Appendix A of this report.

Definitions Relating to Telemetering

The subcommittee on remote metering has prepared definitions of terms relating to telemetering which by Committee action are given here for comments, which are solicited and should be sent to the secretary of the committee, H. C. Koenig:

Telemeter: Measuring, transmitting and receiving apparatus for indicating, recording or integrating at a distance by electrical means the value of a quantity.

Telemetering: The indicating, recording or integrating of a quantity at a distance by electrical translating means.

Voltage (Type) Telemeter: A telemeter which depends on the variation of a voltage as the translating means.

Current (Type) Telemeter: A telemeter which depends on the variation of a current as the translating means.

Frequency (Type) Telemeter: A telemeter which depends on the variation of a frequency as the translating means.

Impulse (Type) Telemeter: A telemeter which depends on electrical impulses as the translating means.

Duplicate Position (Type) Telemeter: A telemeter which depends on duplicating at the reeciving end changes in angular relation or impedance of the translating means.

Direct-Acting (Type) Telemeter: A telemeter in which the translating means (voltage, current, frequency, etc.) increases in value with increase in the measured quantity.

Inverse-Acting (Type) Telemeter: A telemeter in which the translating means (voltage, current, frequency, etc.) decreases in value with increase in the measured quantity.

Note: In the above definitions the word "type" has been included in order to make clear the characteristic being defined. It is hoped that, after these definitions have more common application, the word "type" may be dropped and the terms used understood.

It is suggested that a telemeter which measures
Current be called a teleammeter.
Voltage be called a televoltmeter.
Watts be called a telewattmeter.

Measurement of Starting Currents in Fractional Horsepower Motors

A subcommittee has prepared the following report relative to measurement of starting currents in fractional horsepower motors.

"In 1925 one of the large middle western power companies undertook an independent investigation into the operating characteristics of fractional-horsepower motors. This investigation was started because of the numerous service calls due to flicker in lamps caused by the starting of small motors operated from the same lighting circuit.

"A paper on this subject was read at the 1925 annual meeting of the Association of Edison Illuminating Companies. Shortly thereafter a joint committee was formed which included representatives from the Association of Edison Illuminating Companies, National Electric Light Association, National Electrical Manufacturer's Association, the American Washing Machine Manufacturers' Association and various individual manufacturers of small motors and of motor-driven domestic electrical equipment. This committee held several meetings in 1927, 1928 and 1929, resulting in the setting up of specifications for performance of fractional-horsepower motors. These specifications are

in use and are readily applied in all particulars except the limitation upon starting current.

"In the specifications of the joint committee and also in other specifications issued by various engineering societies, starting current has been defined as the reading obtained on a well-damped ammeter. Efforts to determine compliance with the specifications of the joint committee brought about discussions as to the methods of measuring such starting currents. It was suggested at the meeting of the Instruments and Measurements Committee held on November 29, 1929, that the question of measuring starting currents could very well be considered by a subcommittee. A subcommittee was appointed to investigate the question, and report to the main committee.

"The starting current taken by a fractional-horsepower, single-phase motor persists for a relatively small number of cycles.

"In the case of repulsion-induction motors, the maximum current drawn in the first cycle falls rapidly in successive cycles, is suddenly increased momentarily by the action of the short-circuiting device on the rotor, and then quickly reduces to the normal running current.

"In the case of split-phase motors, the initial input may persist for from 6 to 15 or 20 cycles, and is then rapidly reduced to the normal running current.

"The ideal instrument for the measurement of starting currents would, of course, be the oscillograph. There is no question that the oscillograph represents the true conditions in the motor circuit during the starting period. Because of its expense and bulkiness, however, the oscillograph does not readily lend itself to the measurements of starting currents in the field.

"On the other hand, readings of an ammeter must be interpreted in terms of damping and inertia of moving parts, personal equations, and the magnitude and duration of the starting current as actually recorded by the oscillograph.

"In other words, we have at least five variables to be considered in setting up any standard method for measurement of starting currents for small motors.

1. Meter damping.
2. Inertia of moving elements of meter.
3. Initial amplitude of starting current.
4. Duration of starting currents.
5. Personal equation.

"The nearest approach to the oscillograph in an a-c. instrument would be one which is critically damped and has such a short period (by reducing the moment of inertia or increasing the restoring torque) that its pointer would follow exactly the changes current. Such an instrument must have a period of the order of 0.01 second or less, which naturally places it outside the class of ordinary a-c. ammeters.

"The action of a current of short duration on the ordinary a-c. instrument has a ballistic effect, but unfortunately this effect is not proportional to the current or its square, but depends upon $\int i^2 \, d\, t$, which shows that the same indication would result for widely differing currents provided they had correspondingly different durations. This effect is further complicated by the fact that the electromagnetic constant of the instrument varies greatly throughout its scale, so that the ballistic effect depends in addition upon the duration of the current relative to the responsiveness of the movable system, which differs among instruments of various manufacturers and even among instruments of the same manufacturer.

"It seems evident therefore that the simple indication of any of the ordinary a-c. ammeters cannot be used as a measure of current for short durations, such as motor starting currents.

"Since the origin of this investigation was concerned with the flicker effect upon lamps, it seemed logical to study motor starting currents in relations to the physiological perception of flicker. Recent studies have tended to show that the physiological effect of flicker produced in the starting of motors was approximately proportional to the locked-shaft current.

"In view of the above facts the committee recommends the use of an ammeter equipped with an adjustable backstop, by means of which the pointer can be initially set at any place upon the scale. By making several trials, a point can be found from which the pointer moves but very slightly upon the starting of the motor. This point has been found to be the maximum current drawn by the motor in starting. In other words, it is approximately equivalent to the locked-shaft current. This meter therefore, permits the measurement of locked-shaft current without the attendant difficulties due to heating.

"The committee has not attempted to devise a new instrument for the purpose of measuring starting currents, for the instrument referred to has already been used for this and other work and can be made by any of the instrument manufacturers."

Standard for Recording Instruments

A tentative draft of Standard for Recording Instruments has been prepared, using Instrument Standards No. 33 as a basis and making necessary modifications and additions. The latest copy of this tenative draft is now being circulated to members of the subcommittee on recording instruments, and to other instrument manufacturers who are not represented on the Committee.

Revision of Standard No. 14—Instrument Transformers

A subcommittee has been appointed to revise Standard No. 14. Mr. E. J. Rutan is Chairman of this subcommittee.

Convention of Phase Angle in Instrument Potential Transformers

Present A. I. E. E. Standard No. 14, Par. 59 provides that for instrument potential transformers, the phase angle is conveniently considered as negative when

the reversed secondary voltage vector leads the primary voltage vector. This convention, however, has not been universally followed. To harmonize procedure, the Committee has recommended to the Standards Committee that the rule be changed to provide that the phase angle be considered as positive when the reversed secondary voltage vector leads the primary voltage vector.

Standard on the Technique of Temperature Measurements

The Committee hopes to complete the work on this Standard during the coming year.

Reactive Power

The Committee is studying the question of the measurement of reactive power.

Papers

A total of twelve papers was reviewed during the year, eight of which were presented, as follows:

Measurement of Electrical Machine Characteristics

A Recording Torque Indicator that Automatically Records the Torsional Effect of Motors during Acceleration, G. R. Anderson, A. I. E. E. Quarterly Trans., Vol. 49, p. 333, January 1930.

Determination of Generator Speed and Retardation during Loss Measurements, O. E. Charlton and W. D. Ketchum, Northeastern District Meeting, Springfield, Mass., May 1930.

Measurement of Temperature

A Self-Compensating Temperature Indicator, I. F. Kinnard and H. T. Faus, A. I. E. E. Journal, Vol. 49, p. 343, May 1930.

Measurement of Light

An Ultra Violet Light Meter, Dr. H. C. Rentschler, A. I. E. E. Quarterly Trans., Vol. 49, p. 546, April 1930.

Oscillographs

Design and Application of a Cathode Ray Oscillograph with Norinder Relay, O. Ackermann, A. I. E. E. Journal, Vol. 49, p. 285, April 1930.

A New Portable Oscillograph, C. M. Hathaway, North Eastern District Meeting, Springfield, Mass., May 1930.

Network Analyzer

The M. I. T. Network Analyzer, H. L. Hazen, O. R. Schurig, M. F. Gardner, North Eastern District Meeting, Springfield, Mass., May 1930.

Air Capacitors

Phase Difference in an Air Capacitor, W. B. Kouwenhoven and C. L. Lemmon, North Eastern District Meeting, Springfield, Mass., May 1930.

Conclusion

The interest of the members of the Committee on Instruments and Measurements has been maintained in its activities during the past year, resulting in definite action on several subjects. The study now being given to present projects should result in further definite action next year.

APPLICATIONS TO IRON AND STEEL PRODUCTION*

To the Board of Directors:

The unprecedented activity in the iron and steel industry, which resulted in record production of steel during 1929, is also indicated by the number of rolling mill electric drives purchased and installed.

Last year it was pointed out that synchronous motors for driving constant speed mills were increasing in number every year and this has been especially noticeable during the past year. Synchronous motors are desirable in any kind of constant speed mill application where the peak load conditions are not of sufficient size to interfere with the capacity of the power plant. One of the largest single installations of synchronous motors so far is that at the national works of the National Tube Company at McKeesport, Pa., where six large synchronous motors will be used for driving two seamless tube mills.

Hand-to-mouth buying by users of rolled steel products is one of the factors responsible for single mills being required to roll during one day small tonnages of a considerable variety of products. To meet this condition, the mills must be extremely flexible and this flexibility is most readily obtained by using individual adjustable-speed motor drive for all or many of the roll stands. An interesting example of this is a 15-stand, 10-inch merchant mill at the Indiana Harbor Plant of the Inland Steel Company which will be driven by 13 adjustable-speed d-c. motors, totaling 4900 hp.

The past year saw the application of the first twin motor drive to a blooming mill. The development of this idea has been carried on for some time and was probably an outgrowth of the idea of the individual stand drive which has been carried on for the past several years, on various types of billet, strip and skelp mills. The advantage of this type of drive is readily appreciated inasmuch as it eliminates the pinion stand with its losses and maintenance and at the same time permits a variation in roll diameter thus eliminating matching of rolls and permitting flexibility in the mill operation.

There is a continual demand from the steel plant operators to reduce delays and maintenance costs, and great strides have been made in the application of magnetic control in various motor drives.

There has also been further development in the automatic screw-down, which the year 1929 saw applied to plate mills and structural mills.

Development in the application of voltage control

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A. C. Cummins,	F. O. Schnure,	T. S. Towle,
S. L. Henderson,	W. B. Shirk,	J. D. Wright.

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has continued to show the following advantages: less maintenance, ease of operation, faster manipulation of the screw-down, and simplicity of control. All of these factors are of vital importance and result materially in improved efficiency and increased production of the mills.

The control for reversing mill motors has been improved. This improvement includes the advantages gained on voltage control as applied to screw-downs, and simplified voltage control of reversing mill drive by controlling the fields of individual exciters for the motor and generator fields of a reversing mill drive. This has greatly reduced the maintenance on the field control equipment for reversing mills and has permitted simpler and more sturdy apparatus for field control. It has practically eliminated the high inductive arc on the field control panel contactors when a mill motor is accelerated and decelerated.

During the past year the installation of photoelectric cells for use as flag switches has incresed. In addition, the successful operation of the photoelectric cell has created other uses, such as direct and recording temperature indicators to replace the present pyrometer counters for sheets, tubes, billets and ingots, fire prevention, etc. The field for this little device is spreading rapidly and the demand for photo-electric cells in the steel mills in the next few years will be greatly increased. The design of this apparatus lends itself to practically any application where it is desired to automatize a mechanical operation or adjust an operating condition to obtain increased production.

Extended research and experiment are being made in the economical use of fuel in steel mills. The electrically operated recording calorimeters and electrically operated gas meters are being used to control the combustion automatically and more economically.

The use of electric welding has developed enormously in the steel mills. Particularly of note is the development in the electric welding of steel tubes.

A new mill which eliminates all hand and mechanical puddling, has been completed at Pittsburg for the manufacture of wrought iron. This plant is electrically equipped throughout and is the most modern mill in the world electrically operated for the manufacture of wrought iron. The method of operation consists essentially of pouring molten iron over molten cinder in a ladle under suitable conditions to form a ball. This ball is then formed by a powerful motor driven press into a bloom which in turn is rolled down in the electrically operated blooming mill to muck bar or billets preparatory to being sent to the skelp mills.

Up to this time the limiting feature in the wrought iron industry has been the economical inability to produce wrought iron on a quantity basis. As a result, the principal use of wrought iron has been confined to the manufacture of pipe. With the development of this new method of making wrought iron on an economical quantity basis there will undoubtedly be markets opened to it where previously it was unable to compete.

The growth of blast furnace production is being greatly assisted by the automatic operation of skip hoists, the application of stock line recorders, pyrometers and other features that tend to give the furnace operators more information regarding their operation.

SHORT-WAVE HIGH-POWER RADIO TUBE

Vacuum tubes have been subjects of research for years. Approximately three years ago scientists in General Electric Research Laboratories succeeded in constructing a radio tube having a wavelength of six meters and a frequency of 50,000,000 cycles per second, capable of radiating 10 to 15 kilowatts of energy. This is fifty times as much power as any short-wave tube previously had been able to produce.

Early experiments with this tube were accompanied with some phenomena startling to a layman. Within the sphere of its influence a cold copper bar would blister the hand that picked it up; an incandescent lamp held in the hand, without wire connections with any electric circuit, would light to full brilliancy; similarly a neon tube, upon being touched by anyone, would emit its bright red glow. Electrical instruments, even in rooms other than the one where the tube was, were disturbed or broken. Persons approaching too close to the tube experienced suddenly a comfortable glow of warmth, but if they continued under the influence, increasing pain in limbs and joints. Blood temperatures rose to 100 degrees Fahrenheit in fifteen minutes.

Radio cooking was demonstrated as a possibility. A wire was suspended over a table at a distance of a few feet from the radiating aerial, which was a copper bar about ten feet long. A sausage in a glass container suspended from the end of the wire was soon cooked. Likewise an egg was "fried" in this container, and an apple spitted on the end of the wire was thoroughly baked in a short time. With suitable changes of utensils cookies were baked and water boiled. There were no flames nor other visible evidences of heat accompanying the cooking.

The vacuum tube from which this weird power emanated was only two feet long and five inches in diameter. However, auxiliary to it was a large and complex array of electrical equipment costing so much that the tube will have but little practical utility until researchers and developers shall have accomplished numerous simplifications.

Quite different applications of the capabilities of this tube have also been under investigation. For generations heat has been used to alleviate pain and cure some diseases. * * * * As yet the high-power short-wave vacuum tubes are being used for experimental purposes only. To bring them into practical usefulness at reasonable cost and discover their many possibilities for service to mankind is now our task.—Willis R. Whitney, in Engineering Foundation *Research Narrative.*

Abridgment of

Transmission Research and Design
With the Field as a Laboratory

BY F. E. ANDREWS* and C. L. STROUP†
Member, A. I. E. E. — Associate, A. I. E. E.

Synopsis.*—Overhead transmission lines are usually considered to be a class of equipment subject to certain types of troubles which cannot be avoided by means accepted in ordinary practise. It is the purpose of this paper (1) to describe improvements in design of wood pole lines of the 33,000-volt class, which improvements have been developed and applied to the system with which the authors have been identified and which it is believed will greatly reduce the characteristic troubles; (2) to present an explanation of flashovers on wood structures; (3) to give the facts found in field investigations which form the basis for the improvements adopted: (4) to describe the method used for field investigations and analysis of troubles.*

The studies and investigations referred to deal primarily with the matter of insulation. Considerable information, relative to the insulation values of wood in a structure, as developed by laboratory tests has been published. Experience is cited to show the value of wood insulation in the structure developed from field experience on 33,000-volt lines, and there is presented a practical economical design of wood pole structures using wood braces in place of the usual metal braces which seem practically immune to lightning troubles. Data from laboratory tests are given to substantiate conclusions developed in the field investigations. The performance of insulators with respect to mechanical and electrical breakage is shown, and the use of insulators of more sturdy design is discussed.

* * * * *

Introduction

THE concentration of electric power generation in a few large stations, and the distribution of the power by means of extensive transmission systems, has made the reliability of the transmission lines a matter of paramount importance. Therefore, reliability must receive increased attention in the design and operation of transmission lines.

During the past few years, the remarkable engineering progress which has been made in improving the operation of the higher voltage lines has overshadowed the problem of the lower voltage lines, until recently it being assumed that these have been as satisfactory in design as was possible. This paper deals with the investigations and experiences of the authors with these lower voltage lines which directly serve most of the important loads.

The system with which the authors have carried out their work consists of a 12,000-, and 33,000-volt network in the north eastern part of Illinois, supported by a 132,000-volt system which interconnects the generating stations. This is part of the Chicago region power pool.

For the 12,000-, and 33,000-volt lines, wood pole construction of the conventional design is in general use. This consists of a 10-ft. crossarm with a 5-ft. steel brace, carrying the three conductors on 45,000-volt insulators. Except in special cases, structures are not grounded; overhead ground wires are not used except on a few of the older lines.

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1. For references see Bibliography.

Presented at the North Eastern District Meeting of the A. I. E. E., Springfield, Mass., May 7-10, 1930. Complete copy upon request.

Investigations of Line Performance

Experience with the 132,000-volt system has demonstrated the benefits to be derived from the investigation and analysis of interruptions and indicated that it should be possible to improve the operation of the lower voltage lines.

A plan of analyzing operation records and investigating cases of trouble was established, and within a short time after being put into operation, brought forth important information relative to the influence of the various factors affecting the transmission system operation. This also showed just what was taking place when lighting interruptions occurred.

The most important items of field investigation were those investigations in as many locations as possible where trouble occurred, inspection of all insulators replaced, and a pole climbing inspection at a number of locations selected for special study.

Table I shows the line performance with respect to lightning and insulator damage and the comparison of the operation of lines of different voltages. The trip-outs due indirectly to lightning are those caused by associated disturbances on lines other than the one on which the fault occurs. The 33-kv. direct trip-outs exceed the flashover locations found because sufficient evidence of flashover was not always visible from the ground.

It is significant that the 33,000-volt line trip-outs directly due to lightning are 45 per 100 mi. per year, of which 36 per 100 mi. were located. Of the 36 trip-outs, 11.5 were on grounded structures while 15 were on plain structures; 9.5 were on guyed structures where flashover-to-ground over the guy may or may not have occurred.

Table II shows the classification of line interruptions according to causes. It will be noted that lightning

was directly responsible for 35.7 per cent of the interruptions. Interruptions due to defective insulators, of which there are a large number on the system, were relatively few,—1.8 per cent.

TABLE I
SYSTEM MILEAGE AND SUMMARY OF LIGHTNING FLASHOVER AND INSULATOR PERFORMANCE, 1929

Mileage	132-Kv.	33-Kv.	12-Kv.
Wood pole construction	0	1045	130
Steel tower construction	297	25	10
Operating Record			
Line trip-outs due directly to lightning per 100 mi	1	45	15
Line trip-outs due indirectly to lightning per 100 mi		26.5	12
Total cases of insulator flashover located per 100 mi	1	36	28
Cases of insulator flashover located on lines with overhead ground wire per 100 mi. of this type line	1	20	..
Cases of insulator flashover located on grounded structures per 100 mi	..	11.5	6.9
Cases of insulator flashover located on structures with guys but no grounds per 100 mi	..	9.5	7.1
Cases of insulator flashover located on structures not guyed or grounded per 100 mi	..	15	14
Cases of insulator flashover located on pole top switches per 100 switches	..	11	3.3
Cases of insulator flashover located on steel towers per 100 towers	..	7	4.2
Number of insulators changed due to electrical damage per 100 mi	5.15	75	58.5
Number of insulators changed due to external breakage per 100 mi	8.1	139	204

TABLE II
CLASSIFICATION OF LINE INTERRUPTIONS RESULTING FROM AUTOMATIC OPENING OF OIL SWITCHES 12-KV. AND 33-KV. LINES JAN. 1—DEC. 31, 1929

Cause	Per cent of total interruptions
Lightning, direct	35.7
Lightning, indirect	22.7
*Failure of insulators other than during lightning storms	1.8
Failure of system equipment external to the line	5.1
System disturbances exclusive of those due to lightning	18.5
Accidents	4
Trees	0.8
Wind, snow, ice or other atmospheric conditions	1.8
Animals	0.4
Operating errors	0.9
From lines interconnecting with other companies	2
Unknown	6.3

*Due principally to insulators with cracked porcelain parts which failed during wet weather.

Lightning Flashover

The best construction of the type generally used for wood pole lines and the use of better and higher voltage insulators have been ineffectual in improving the light-lightning performance. It was accordingly found necessary to consider other means to decrease the susceptibility of lines to lightning.

Inspections were made of structures where flashovers had occurred; burns and arc paths were located on various structures as illustrated by Figs. 2 and 3. The results of the inspections are classified in Table III.

TABLE III
ANALYSIS OF PATH OF FLASHOVERS ON WOOD STRUCTURES

Type of structure	Figure	Number of structures inspected	Number of structures on which no burns were found	Phase-to-phase burns only	Phase-to-ground or guy burns on one or more phases
Steel brace, wood crossarms, with no guys and no grounds	2-B	14		14	
Steel crossarm, no guys, no grounds	3-A	79	74	5	
Totals,—without guys or grounds		93	74	19	
Guyed or grounded structures	2-A, 2-C	17		1	16
Guyed structure, steel crossarm, no ground	3-B	16	5	7*	4
Total, guyed or grounded		33	5	8	20
Total, all structures		126	79	27	20

*Of these seven, four showed pole splinters between steel crossarm and guy.

The following observations are derived from this information:

1. On poles not grounded or guyed, line-to-line flashovers occur without arcing to ground, the arc utilizing the steel brace with wood crossarm construction, or the steel crossarm, as part of the short-circuit path.

2. On grounded structures, the flashovers are from line to ground, usually involving more than one phase. The flashovers to ground of the different phases on any one structure may or may not occur simultaneously.

3. On guyed structures, flashover often occurs from line to ground; or, with the guy separated on the pole from the steel arm or brace, line-to-line flashovers frequently occur without power arcs to ground.

Observations and study lead to the conclusion that flashovers on 33,000-volt wood-pole non-grounded construction occur at lightning surge voltages much below those required to spark over the entire structure, and that these flashovers are phase-to-phase rather than from line to ground. All information available, including that in Tables I and III, shows that flashovers are reasonably well divided between ungrounded (or unguyed) and grounded (or guyed) structures.

The following explanation of power flashovers on plain structures is offered. When lightning surge voltage appears on a conductor, the voltage distribution between line and ground over the insulators and structure is such that the voltage stress over the insulator, or between line and crossarm brace, is high enough to cause spark-over or incipient sparks between line and brace only, at voltages lower than those required for structure spark-over. The 60-cycle voltage on the line causes a power arc to follow over the simultaneous

lightning sparks from more than one conductor to brace, and a short circuit is established from line to line through the brace.

The formation of the incipient lightning spark over the insulator at voltages much below those required for structure spark-over to ground has been verified by laboratory tests upon wet poles. On dry poles, insulator

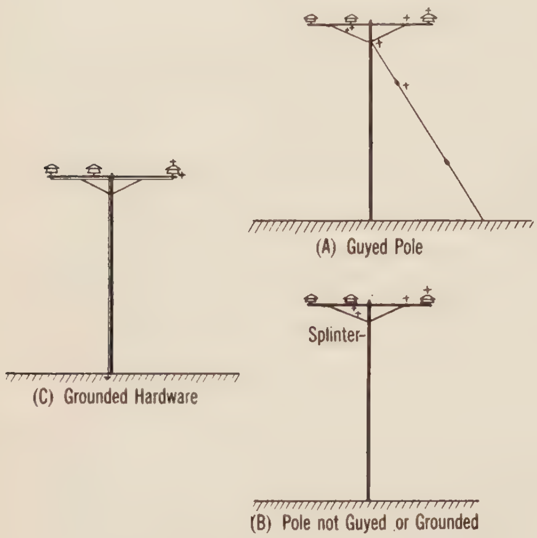

Fig. 2—Conventional Construction. + Indicates Burns

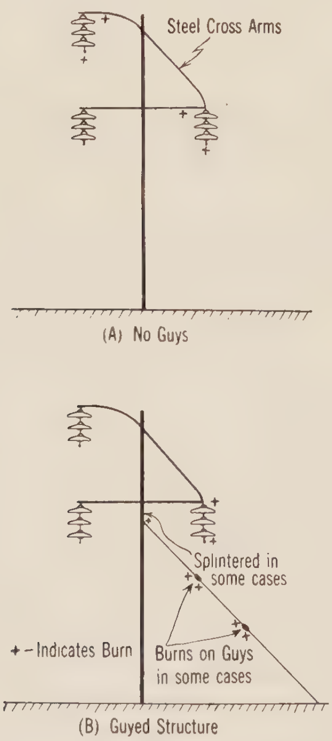

Fig. 3—Steel Arm Construction

spark-over occurred at about the same voltage as structure spark-over.

New 33,000-Volt Structure Design

As a result of the lightning flashover investigation, the design of wood pole construction was changed to make more effective use of the inherent impulse-insulation value of wood, and to eliminate the short-circuiting effect of the steel crossarm brace. The new design is illustrated in Fig. 4. With this design, it is believed that the only flashovers occurring will be caused by lightning voltages of such magnitude as to cause complete structure flashover to ground, which is much higher than usually takes place.

Line insulation and conductor spacing have been increased at vertical corners. Wood insulators have been installed in the guy wires.

Increased phase separation and use of an insulating wood framework have been worked into pole-top switch design.

Since the line flashover value has been increased without increasing that of station equipment, the use of lightning arresters and reduced line insulation near stations is being depended upon to prevent interruptions due to flashover or breakdown of station equipments

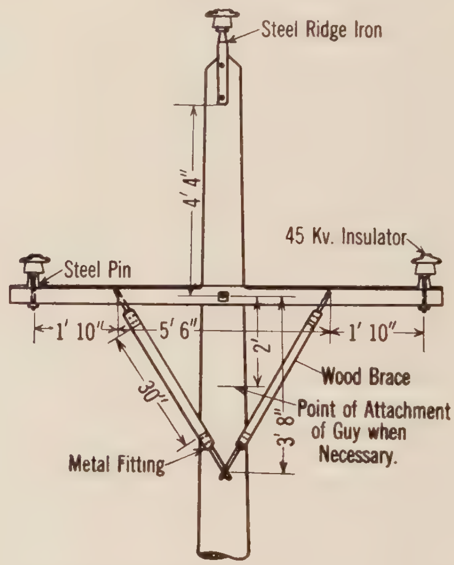

Fig. 4—New Design, 33,000-Volt Wood Pole Construction

and the resulting damage. Fused arcing rings are also being used in certain locations, such as on steel towers and on the old design of grounded pole-top switches, to prevent interruptions due to flashover at these susceptible points.

Overhead Ground Wires

The performance record of certain wood pole lines formerly equipped with overhead ground wires has showed no consistent difference in the number of lightning interruptions after the ground wires were removed. Table IV shows the two-year performance record of three lines with overhead ground wires. It is interesting to note that 36 interruptions per 100 mi. are closely comparable to 45 interruptions per 100 mi. for the entire system as shown by Table I.

It is obvious that the overhead ground wires as installed are not a determining factor in the number of lightning interruptions which occur, as many lines

without the ground wire have better records than those given in Table IV.

TABLE IV
LIGHTNING PERFORMANCE OF LINES WITH OVERHEAD GROUND WIRES

Line	Length in miles	Number of trip-outs directly due to lightning, 1928, per 100 miles	Number of trip-outs directly due to lightning, 1929, per 100 miles
A	31.13	29	51
B	26.44	33	57
C	30.82	20	10
Total*	88.39	27	36

*Totals figured by adding all trip-outs and dividing by total miles.

The ground wire is not so effective on a wood structure as on a steel tower because it reduces the flashover value of the wood structure in considerably greater proportion than it reduces the surge voltage on the conductors.

It is probable that wood pole lines without metal crossarm braces but with well insulated guys, built without overhead ground wires, will withstand most lightning surge voltages without flashover between conductors. If pole splitting from lightning is serious, protective gaps can be used which will maintain the necessary structure insulating value.

Insulator Performance

Insulator damage is an item of major importance in relation to other items of transmission line operating expense. This is evident from the last two items of Table I and the records of insulator damage shown by Table V. Replacements due to external breakage are shown to be nearly three times those due to electrical damage.

TABLE V
CLASSIFICATION OF INSULATOR DAMAGE PER 1000 IN SERVICE OF EACH TYPE

Nature and extent of damage	Electrical damage		External damage	
	Two-piece	Three-piece	Two-piece	Three-piece
Small burn (not bad enough to replace)	0.485	0.188		
Flashed but not broken	2.4	1.22		
Small chip			4	4.3
One skirt broken	2.34	1.32	8.14	4.45
More than one skirt broken	0.429	0.259	1.11	0.812
Shattered	0.543	0.364	0.0286	0.0941
Broken but unclassified	0.485	0.412	3.4	2.07
Total	6.69	3.76	16.7	11.7

Total two-piece insulators in service—35,000
Total three-piece insulators in service—85,000

It will be noted that the breakage of the two-piece insulators is considerably greater than that of the three-piece type. A large number of the latter is in service with shell cracks. The records indicate that there is little difference in the susceptibility to lightning flashover between obsolete insulators (many with shell cracks) and modern insulators. The data, however, show that the latter are much more susceptible to shattering when flashover does occur than the former. It appears that insulators with only top-shells cracked do not seriously affect the operation of the lines. Data show that the shell cracks in the older types of insulators form an important factor in conductor and structure failures, as indicated by Table VI.

TABLE VI
NUMBER OF CASES OF CONDUCTOR OR STRUCTURE FAILURES AS INFLUENCED BY INSULATOR CRACKING

	With insulators free from cracking	With insulators subject to cracking
Conductor burned down due to lightning flashovers	22	19
Conductors burned down due to insutor failure (not lightning)	0	19
Total	22	38
Structure burned due to insulator failure (not lightning)	0	103

Studies of the records from individual lines showed high breakage peaks in the vicinity of schoolhouses. Laboratory investigation indicated that thick porcelain one-piece insulators were much more resistant to external breakage than the conventional multi-part units. Accordingly, trial installations of these were made at some of the high breakage points referred to above with the result that there has been no further breakage with over a year's experience.

Consideration of the above facts, together with other points such as dependability of manufacturing processes and freedom from some of the causes which are believed to have contributed to past troubles with multi-part insulators, has led to the installation of about 5000 one-piece thick porcelain insulators during the past year. During 1929, only five replacements on account of breakage were required of this type.

Conductor Failures

A study of the cases of conductor failures due to the arc following lightning flashovers indicated that the susceptibility of wires to burn-down is a function of conductor size. The smaller sizes, (No. 1/0 and smaller), show more cases of this kind of conductor failure than the larger sizes.

Conclusion

1. The lightning performance of wood pole lines of moderate voltage can be greatly improved by making use of the inherent insulating value of wood; by the elimination of bonding or partial bonding between insulator supports, such as results from the use of steel crossarms or steel crossarm braces; by increasing conductor separation; and by the use of wood, or other insulators, in guys.

2. Overhead ground wires as usually installed on wood pole lines do not materially improve the operation of the lines.

3. Insulator breakage can be greatly reduced by the use of more sturdy insulators.

4. Systematic study and careful analysis of field investigations and of records of operations and troubles, together with the intelligent interpretation of summaries and final analyses, can result in great improvement in system reliability and in better utilization of investment.

ACKNOWLEDGMENTS

The authors express their appreciation of the cooperation and assistance given them by Mr. F. W. Peek, Jr., of the General Electric Company, and his staff at the Pittsfield Laboratory, in obtaining the laboratory test data required, and for advice given on the problems discussed in this paper. They also gratefully acknowledge the help given by their associates and by the management of the Public Service Company of Northern Illinois in securing and making available the information contained in the paper.

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Abridgment of

Effects of the Magnetic Field on Lichtenberg Figures

BY C. EDWARD MAGNUSSON[1]

Fellow, A. I. E. E.

Synopsis.—*This paper deals with new forms of Lichtenberg figures produced under the combined stress of dielectric and magnetic fields. The effects produced by the magnetic field may be used for determining whether electrons, positive ions, or protons, are basically the active elements in the formation of the positive as well as the negative figures. The illustrations also show that the presence of the magnetic field greatly extends the range of air pressures within which figures of definite form can be obtained, that figures taken at low air pressures possess structures strikingly different from those hitherto known, and that these figures may prove a key to the mechanism of the electric spark.*

* * * * *

MANY extensive investigations have been made to ascertain the nature of Lichtenberg figures and lately, of their use for recording certain characteristics of electric surges and impulses, for measuring short time intervals, etc.; but no attempt seems to have been made to determine what effects, if any, would be produced on the figures if formed under the stress of the magnetic field. That a reaction should be expected if the figures are formed by rapidly moving electrons, ions, or protons, as has been postulated in the several theories advanced to explain the phenomena, is evident.

The experimental results are in fact striking and provide the means for determining whether electrons, ions, or protons, are basically the active elements in the formation of the positive as well as the negative figures.

A diagram of the electric circuit[2] and the arrangement of the apparatus used is shown in Fig. 1, and a cross-section of the plate holder loaded with two plates as used in the first part of the work is shown in Fig. 2.

By using two plates as shown in Fig. 2, the number of exposures was cut in two, and, what is of greater importance, both the positive and the negative figure were obtained for the identical spark or impulse.

For all the figures illustrating this paper, the direction of the magnetic lines of force was perpendicular to the plane of the photographic plate; the direction of the field could be reversed by means of a double-throw field switch. On the legend below each figure, the direction of the magnetic field with respect to the printed page is indicated by the letters N or S. The letter S indicates that the south pole was in front, and the north pole back, of the printed page; that is, the direction of the magnetic lines of force is towards the reader. The notation N indicates the reverse of S.

Under each figure, the legend gives the quantitative

1. Professor of Electrical Engineering and Director Engineering Experiment Station, University of Washington.

2. *Leichtenberg Figures*, A. I. E. E. JL., Vol. XLVII, 1928, p. 830.

Presented at the Summer Convention of the A. I. E. E., Toronto, Ontario, Canada, June 23-27, 1930. Complete copy upon request.

data for the conditions under which the exposure was made. The air pressure is given in cm. Hg.; the spark-gap spacing in cm.; the direction of the magnetic field, N or S; the field strength in lines of force per cm.^{2}; the polarity of the electrode in contact with the emulsion side of the plate as + or − ; and finally, the number of the corresponding figure in the pair, produced by the same impulse.

The Negative Figure. For the range of air pressures and impressed voltages represented in Figs. 3 to 5, the main effect produced by the magnetic field on the negative figures is the bending of the rays; *clockwise* if the magnetic lines of force are in the N direction as in Fig. 5, and *counterclockwise* if the field is in the S direction as in Fig. 3.

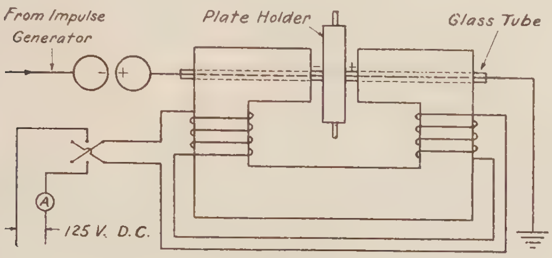

Fig. 1—Circuit Diagram

The observed reaction on the negative figure is in full accord with the generally accepted theory which is based on the postulate that under the impulse voltage-gradient, streams, rays, or waves of electrons are projected radially from the negative electrode at high velocity over the emulsion surface of the photographic plate. The effect of the magnetic field in bending the otherwise radially projected rays or streamers is in accord with this assumption. Thus in Fig. 5 the direction of the magnetic lines of force is N; that is, from the reader through the printed page. A stream of electrons projected radially from the negative electrode over the photographic plate, and therefore at right angles to the magnetic field, should be deflected in a clockwise direction precisely as shown in the figure.

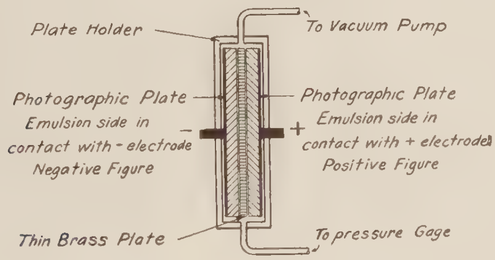

Fig. 2—Cross-Section of Loaded Plate Holder

The Positive Figure. For the positive figure, the situation is somewhat more complex, and several theories have been advanced to explain its formation.

The experimental evidence hitherto available has been inadequate to either fully establish or refute the proposed theories, but it appears that the reaction of the magnetic field will provide the required criterion.

Let the argument be applied first to the postulates of positive ions or of protons projected outwards from the positive electrode. Consider the direction of motion that positive ions or protons would have at some point,—as a in Fig. 4,—under the combined stress of the voltage gradient and the magnetic field. The magnetic field is in the N direction. The force of the voltage gradient projects the positive charge radially away from the electrode and simultaneously, the reaction of the magnetic field produces a force on the positive ions or protons at right angles to their motion and in the *counterclockwise direction.* The photographic record in Fig. 4 shows the streamers deflected in the *clockwise direction,* and therefore the theory based on the postulates of positive ions or protons as the essential

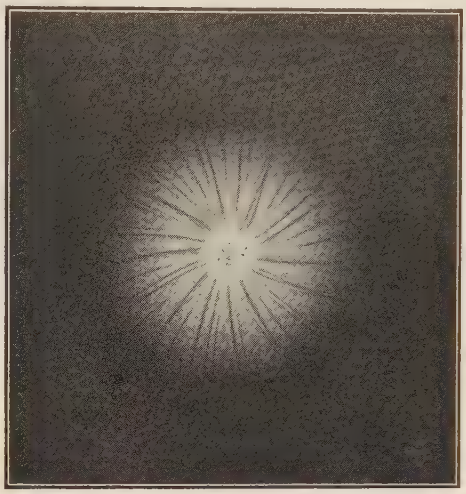

Fig. 3

Pressure 30.0 cm.; Gap 4.0 cm.; Field S, 13,000 cm^2. Electrode − ; Paired with Fig. 5; Neg. No. 136.

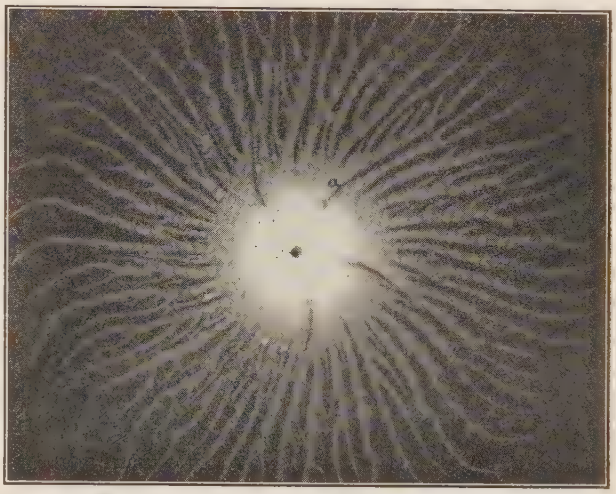

Fig. 4

Pressure 15.0 cm.; Gap 2.5 cm.; Field N, 12,300 cm^2. Electrode + ; Paired with Fig. 8; Neg. No. 171.

elements in the formation of the positive figure does not conform to the experimental evidence.

Let the same argument be applied to the assumption that electrons falling towards the positive electrode are the active elements in the formation of the positive

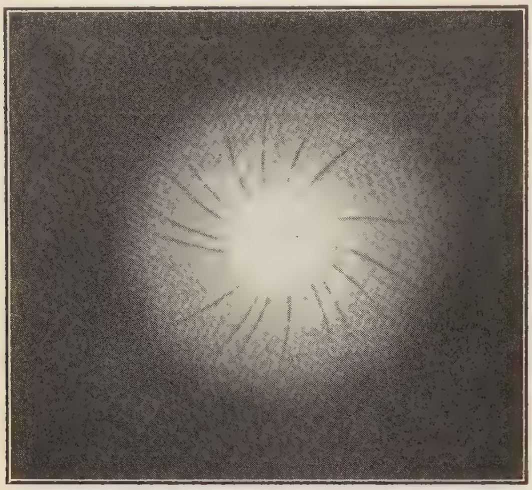

Fig. 5

Pressure 12.0 cm.; Gap 1.2 cm.; Field N, 12,400 cm^2.
Electrode − ; Paired with Fig. 9; Neg. No. 186.

figures. Consider the direction of motion that an electron at the point a in Fig. 4 would have under the combined stress of the dielectric and magnetic fields; the voltage gradient would cause the electron to fall radially towards the positive electrode, while the reaction of the magnetic field would be at right angles to the

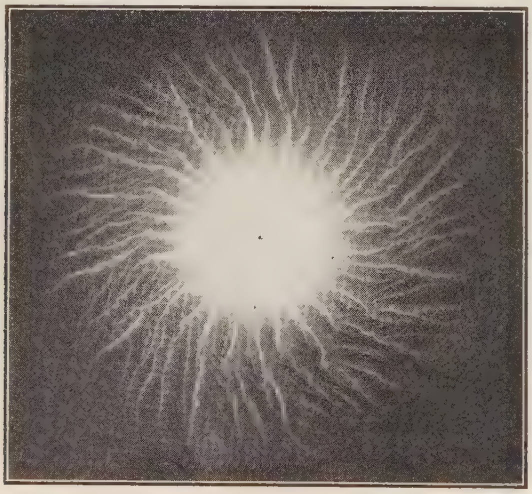

Fig. 6

Pressure 0.25 cm.; Gap 0.5 cm.; Field S, 12,500 cm^2.
Electrode − ; Paired with Fig. . .; Neg. No. 395.

direction of motion of the electron and, in the *counter-clockwise* direction. The resulting curved path, (if the positive electrode is used as the point of reference), would be deflected in the *clockwise* direction; that is, in accord with the form of the streamers in Fig. 4.

The theory based on the postulate of electrons falling towards the positive electrode as the active elements in the formation of the positive figure is supported by Fig. 4.

New Types or Forms of Lichtenberg Figures. In the presence of the magnetic field the range of air pressure within which Lichtenberg figures of definite form and structure can be obtained is greatly extended.

The lower limit of air pressure in which Lichtenberg figures, hitherto taken without the presence of the

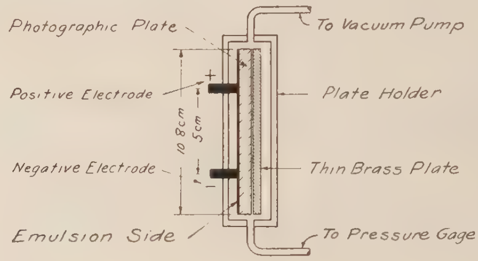

Fig. 7—Loaded Plate Holder

magnetic field have even a semblance of definite form and structure, is approximately 5 cm. Hg. At lower air pressures, the figures lack definition and have the appearance of a nebulous haze or fog. Under the stress of the magnetic field, the results are strikingly different, as evidenced by Fig. 6.

Both Electrodes on One Plate. For Figs. 8 to 10, both electrodes were in contact with the emulsion side of a single plate. The arrangement of the elec-

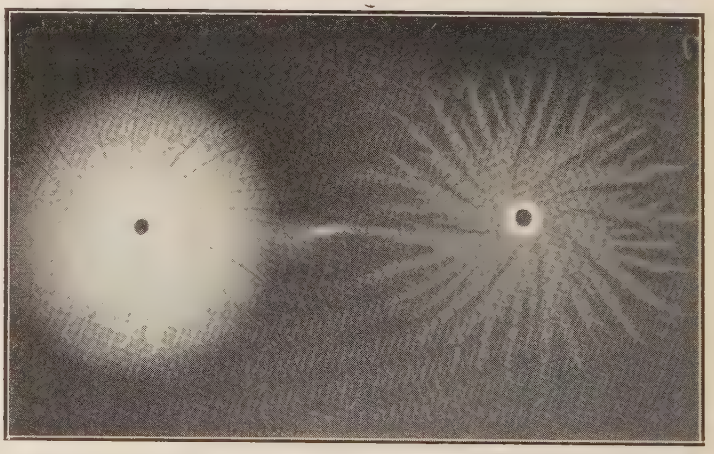

Fig. 8

Pressure 15.0 cm.; Gap 1.0 cm.; Field N, 12,500 cm^2.
Electrode −, + ; Paired with Fig. . .; Neg. No. 394.

trodes, photographic plate, and brass plate, is shown in Fig. 7.

In Figs. 8 to 10 are three exposures showing positive and negative figures for progressively higher impressed voltages and correspondingly greater after effects.

The bending of the streamers in the positive and negative figures is in the same direction, using the electrodes as centers of reference. In Figs. 8 and 9, the magnetic field was in the N direction and pro-

duced clockwise deflections in both the negative and the positive figures. For Fig. 10 the direction of the magnetic field was in the *S* direction and as a consequence, the streamers for both the positive and the negative figures show counterclockwise deflections.

In Fig. 8 the impressed voltage was barely sufficient to form a single connecting bridge or link between the two figures. Due to higher impressed voltages larger number of paths between the two figures is found in Figs. 9 and 10. Each tuft or brush of light formed near the periphery of the negative figure is directed towards, and connected to, a prong or tip of a streamer in the positive figure. It should be noted that the brushes or paths bridging the space between the original Lichtenberg figures are apparently formed after the negative figure, proper, has been completed.

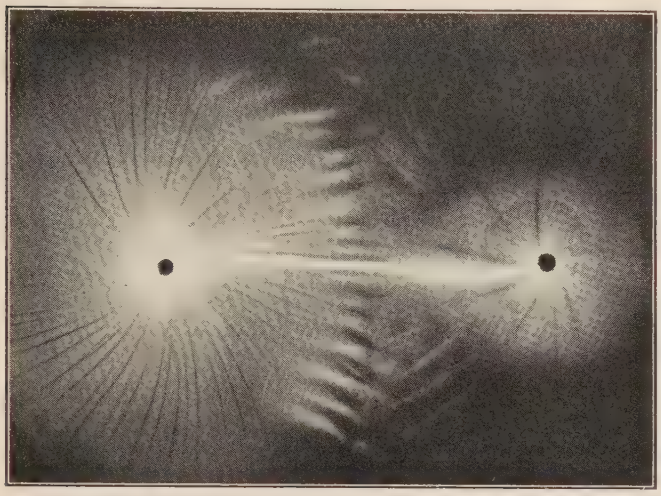

FIG. 9

Pressure 15.0 cm.; Gap 4.0 cm.; Field *N*, 12,500 cm^2.
Electrode −, + ; Paired with Fig. . .; Neg. No. 384.

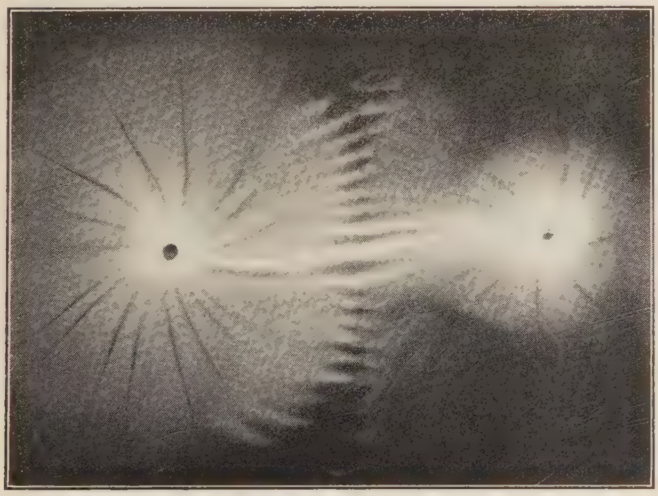

FIG. 10

Pressure 15.0 cm.; Gap 4.0 cm.; Field *S*, 12,500 cm^2.
Electrode −, + ; Paired with Fig. . .; Neg. No. 385.

If sufficiently high voltage persists between the electrodes after the initial figures have been formed the gap between the electrodes is bridged by a sparkover as shown in Figs. 9 and 10.

The path of the sparkover, Figs. 9 and 10, between the two electrodes has sharp zigzag, lightning-like, turns, superimposed on a basic double inflection, which in the main conforms to the deflections of the initially formed positive and negative figures. This indicates that the elements flowing in the sparkover channel are negatively charged; that is, the channel is formed by electrons attracted to the positive electrode and repelled from the negative electrode.

In Fig. 11, under the same conditions as in Fig. 9, the deflections of the positive and negative streamers are indicated by the curved lines extending from the electrodes as centers. It is evident that under the combined stress of the dielectric and magnetic fields, the path of the electrons coming from the negative electrode that pass through the point *a* and flow into the positive electrode follow the solid line curve as drawn in Fig. 11—that is, in a path having a double deflection similar in form to the sparkover path in Fig. 9. On the other hand, positive ions or protons projected from the positive electrode under the same combined stress of the dielectric and magnetic fields, that pass through the point *a* and flow into the negative electrode, as in Fig. 9 must take a path as indicated by the broken line in Fig. 11; that is, a path having a double bend in the reverse direction to that of the sparkover in Fig. 9.

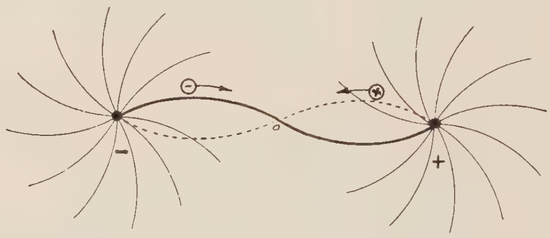

FIG. 11—DEFLECTIONS OF POSITIVE AND NEGATIVE STREAMER

The bending of the streamers, due to the reaction of the magnetic field, increases with decreasing air pressure; but the rate of increase is greater for the positive figures than for the corresponding negative figures.

A fireless, smokeless, odorless and noiseless photographic flash lamp has been developed by the General Electric Company, Cleveland. It consists of a clear bulb of standard design with the flashlight filament coated with a special preparation and with a quantity of very thin aluminum foil sheet crumpled within the bulb which is oxygen-filled. When the circuit is closed, the filament is lighted and in turn, lights the foil. The lamp operates on any 115-volt house supply, or with dry, storage or flashlight batteries. A new lamp is needed for each flash.

Abridgment of

Study of the Effect of Short Lengths of Cable on Traveling Waves

BY K. B. McEACHRON,* Member, A. I. E. E.   J. G. HEMSTREET,† Associate, A. I. E. E.   and   H. P. SEELYE‡ Member, A. I. E. E.

Synopsis.—*Cathode ray oscillographic tests were made of traveling waves passing from an overhead line into short lengths of cable. Single-phase cable lengths of 500 and 1000 ft. were used. Tests were made with a wide variety of conditions, such as cable at end of line, cable between two sections of line, etc. The tests demonstrated that a short length of cable does not act as an effective protective device when connected between station and incoming line. When the incoming wave on the incoming line has a long flat top, several times the cable, length, the crest of the wave passing the cable is decreased only a few per cent by the presence of the cable, although the wave front is sloped off if it was originally very steep. When the wavelength is approximately the same as the cable length, the cable can reduce the transient voltage to less than half of the value without the cable. Recent measurements on transmission lines show that waves do occur with approximately flat tops which are several thousand feet in length. Therefore the cables do not permit the omission of lightning arresters which are means of reducing the potential of overvoltage surges. This confirms the theoretical calculations and the practise of using lightning arresters with cables.*

The resistance of the ground connection of the cable sheath was found to have important effects. With the cable sheath at the end grounded through 28 ohms, a potential of 82 kv. was measured at the sheath and 105 kv. at the cable conductor.

The protective action of lightning arresters was demonstrated by using a gap and various values of series resistance.

The velocity of propagation in the cable was found to be about 61 per cent of the velocity of light. The surge impedance of the cable was determined by several methods. Calculations based on the measured propagation velocity and measured capacitance gave a value of about 50 ohms. Some of the other methods gave values of about 100 ohms.

THERE has been much discussion concerning the effectiveness of cable in reducing the potential of incoming surges, and with regard to methods of protection, both of the cable itself and of connected apparatus.

Recognizing the importance of this problem, a joint investigation by the General Electric Company, the Consumers Power Company, and the Detroit Edison Company was arranged in the summer of 1929.

The General Electric Company furnished a portable impulse generator and sphere-gaps for measuring voltage. The Consumers Power Company supplied the S-19 transmission line, a portable power supply, communication, and trucking facilities. The Detroit Edison Company furnished 1000 ft. of 24,000-volt lead sheath cable and portable cathode ray oscillograph.

Impulse Generator. The portable impulse generator[1] consisted of 40 banks of capacitors each having a capacity of 0.5 μf. The banks were charged in parallel to 20 kv. each and discharged in series according to the Marx circuit. The potential of the generator was reduced by disconnecting part of the banks.

Transmission Line. The transmission line used for the tests was a section of the S-19 line of the Consumers Power Company.[2] The location of the cable for the tests was at Towers 53 to 55, a distance of 5.16 to 5.36 mi. from the impulse generator, which was at the Croton end of the line.

Oscillograph. The oscillograph was of the hot cathode type described by George;[3] with it and its auxiliaries mounted on a truck.

Methods

Cable Divider. A cable divider similar to the one which was described by Gabor[4] was used to reduce the voltage to a value safe for use on the deflecting plates of the oscillograph. By using the cable divider, it was possible to make measurements at each end of the cable without moving the oscillograph. This was of decided advantage.

Determination of Time Scales and Sweeping Speeds. In order to eliminate any doubt as to timing, a 500-kilocycle wave was superimposed on one measured wave for each condition tested.

Test Wave Forms. At different times, as many as five different waves were used. The forms of these are listed in Table I, all waves being of negative polarity:

TABLE I
DATA ON WAVE FORMS USED

Designation	Voltage crest at Tower 53	Time to reach crest ms.	Time to decay to 50% crest ms.	No. of generator banks used	Series inductance henrys
Steep wave low voltage.	92	8	50	7	0
Medium wave low voltage.	120	13-15	40	10	0.002
Slow wave low voltage.	124	27	50	14	0.011
Steep wave high voltage	225	8	15	32	0
Medium wave high voltage.	223	10	20	32	0.002

Preliminary Measurements

Surge Impedance of the Line. Surge impedance was obtained by determining the voltage and current of a traveling wave from measurements on resistance to

*General Electric Company, Pittsfield, Mass.

†Consumers Power Company, Jackson, Mich.

‡Detroit Edison Company, Detroit, Mich.

1. For references, see end of paper.

Presented at the Summer Convention of the A. I. E. E., Toronto, Ont., Can., June 23-27, 1930. Complete copy upon request.

ground at the end of the line.* A value of 620 ohms for the middle conductor was chosen for purposes of calculation.

Surge Impedance of the Cable. The surge impedance of the cable was determined by several methods:

The first was similar to that used on the transmission line.

The second method is based on the reduction of voltage which occurs when a steep wave enters the cable. In Fig. 4 are shown two oscillograms, taken at Tower 53,

Wave on continuous line at Tower 53 — Wave entering 1000-ft. cable at Tower 53

Fig. 4—Oscillograms of Effect of 1000-Ft. Cable on Traveling Wave

one with the line continuous and the other with 1000 ft. of cable in circuit but with the far end of the cable open. The effect of the cable was to reduce the wave from 92 kv. to 30 kv. on the first reflection.

The third method was to calculate the surge impedance by using the measured propagation velocity of the wave through the cable and the measured capacity in the formula $Z = 1/(C\,v)$. The propagation velocity was found to be 61.2 per cent of the velocity of light. The capacity of the cable as measured by a bridge was 0.0373 μf.

In the fourth method the impedance was calculated from the geometrical constants of the cable.

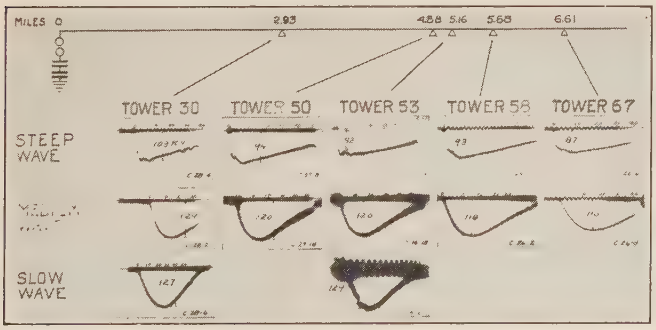

Plate I. Shape of the Waves and Effect of Distance Traveled

These figures for the surge impedance seem to fall into two groups, one about 50 and the other approximately 100 ohms. It is believed that this discrepancy is not due entirely to errors in taking the data, but rather to factors which are not considered.

*This method is described in greater detail in Reference 2.

Results of Tests

The results of the tests are shown in a series of plates on which the oscillograms dealing with each of the subjects studied are grouped.

The oscillograms on Plate I show the time voltage characterisitcs of the three waves used during the tests as recorded by the oscillograph at several locations on the line.

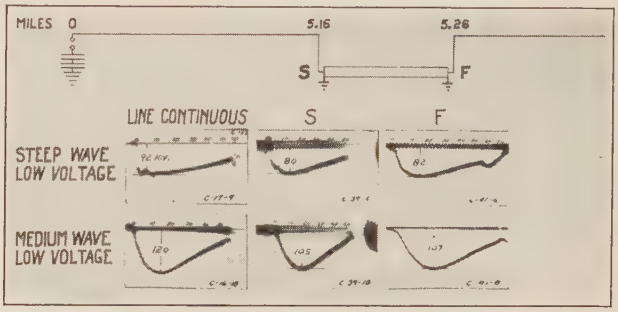

Plate II. Wave Passing Through 500 Ft. of Cable

Plate II. Wave Passing through 5C0 Ft. of Cable. When the wave enters a 500-ft. section of cable, the time for the voltage to rise to its crest value with the steep wave (8-microsecond front) was 12 to 15 microseconds. The crest voltage was reduced from 92 to 80 kv. or about 12 per cent. The amount of reduction

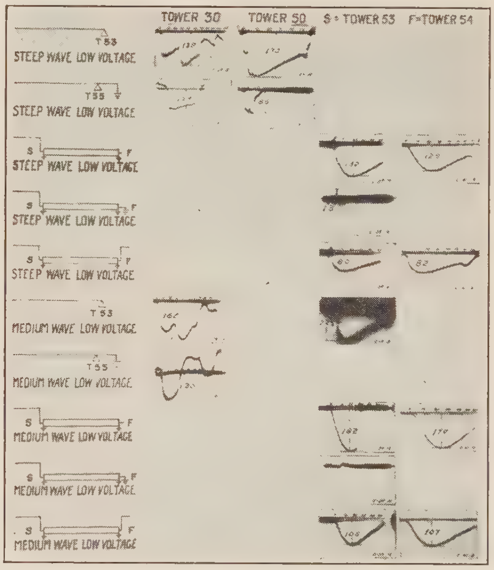

Plate V. Effect of Terminal Conditions

depends principally on the shape of the tail of the incident wave. If the voltage drops rapidly, it will limit the voltage which can be built up in the cable. The wave front of the medium wave was slow enough so that the cable did not have any effect on its shape, although the potential was reduced from 120 kv. to 105 kv.

Plate V. Effect of Terminal Conditions. In Plate V, oscillograms are shown for a variety of terminal conditions.

With line open and with it connected to ground, the reflections with both the steep wave and with the medium wave are clearly defined. With the line open, the reflection adds, while with the line closed to ground, the reflection subtracts.

Ground at "F." The ground at F on the cable conductor holds the voltage at both ends to a low value. With the steep wave, the initial rise in voltage (13 kv.) and two reflections were measured.

Plate VIII. Lightning Arresters. In these tests the lightning arresters were composed of a gap in series with a water tube resistance which was connected between the cable conductor and the sheath.

When a gap with no series resistance was placed between the conductor and sheath, spark-over of the gap started an oscillation in the cable, the frequency of which was determined by the constants of the cable.

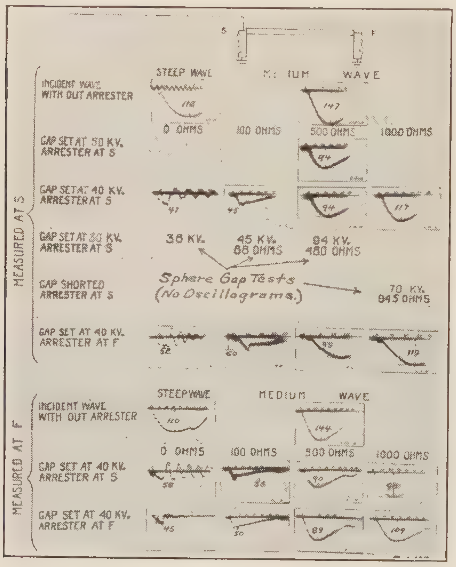

PLATE VIII. LIGHTNING ARRESTERS

With the arrester at F and measurements at S, the reduction in voltage due to the arrester takes place three microseconds later than for the case where the arrester was at S.

With the arrester at S, the wave which passed the arrester was reflected when it reached the open end of the cable.

SUMMARY OF RESULTS AND CONCLUSIONS

1. There was no appreciable change with distance in wave shape for the section of line used. The crest voltages of the waves were close to the critical corona voltage of the line; hence no great attenuation of crest voltage appears, and very little change in the wave front. The distance covered by measurement with sphere-gaps and oscillograms was 3.7 mi.

2. Attenuation of crest voltage was small. In traveling 3.68 mi., the steep wave was reduced 15.5 per cent, and the medium wave was reduced 14.7 per cent.

3. High-frequency oscillations which appear on the front of a steep wave are damped as the wave travels along the line.

4. A wave having a front whose length is short compared to the time required for the voltage to build up in the cable, will be less steep after passing through a cable.

5. The amount of change in wave front for a wave passing through a cable will depend on,

a. The steepness of the wave front.

b. The length of the crest or near crest of the wave.

c. The length of the cable.

d. The values of surge impedance for line and cable.

For a 500-ft. cable the 8-50* wave was changed from an 8-microsecond front to a 12-microsecond front when entering the cable from the line.

For a 1000-ft. cable the 8-50 wave was changed from from an 8-microsecond front to a 24-microsecond front when entering the cable from the line.

6. A wave passing through a section of cable will have its crest value reduced unless the wave has a flat top long enough to cover the time required for the cable voltage to build up by reflections to practically the crest value of the incident wave.

For a 500-ft. section of cable, the crest voltage was reduced 10.8 per cent for both the steep wave and the medium wave.

For a 1000-ft. cable the crest voltage was reduced 24 per cent for the steep wave, 23.3 per cent for the medium wave, and 17 per cent for the slow wave.

7. The propagation velocity was found to be 600 ft. per microsecond in the cable.

8. When a wave passed into the cable, the initial transmitted wave was approximately 30 per cent of the incident wave. This value is dependent on the surge impedance of both line and cable.

9. The two 500-ft. lengths of cable with a short connection between them had practically the same influence on a wave as the single 1000-ft. length of cable.

10. By inserting a 500-ft. connection between the two sections of cable, an oscillation was introduced on the front of the wave passing through the cables. The crest voltages were unchanged by this addition.

11. A short section of cable acts like a concentrated capacity at the open end of a line or at an intermediate point in a line, provided the length of the wave front is long when compared to the time required for the wave to be reflected through the cable. Such a cable or capacitor does not reduce the surge voltage at the connected point if the incident wave has a long flat top.

12. Short lengths of cable cannot be regarded as protective devices for the reduction of overvoltage surges with long flat tops such as often occur in service.

13. Grounding the sheath of the cable at the start S gives the same result as grounding at both ends. When the sheath was grounded at the far end of the

*Rises to 8 microseconds and decays to half value in 50 microseconds.

cable only, the entering wave, measured to ground, had a higher value. This higher voltage was due to the potential between sheath and ground when the sheath was not connected to ground at the start of the cable. After a few reflections through the cable, the wave assumes the same shape whether the cable is grounded at one end or at both ends. This effect is dependent upon the wave-shape and the length of the cable.

14. A traveling wave in a section of cable may be calculated graphically, if the incident wave is given, and the calculated wave will check the measured waves closely.

15. Arrester operation for any type of arrester may be calculated from the volt-ampere curves obtained under similar conditions.

16. The increase in voltage at the other end of the cable from arrester location was about 15 kv. This increase depends upon the steepness of the wave and the length of the cable, and may be estimated for any specific case.

The authors wish to express their appreciation to Messrs. E. J. Wade, W. J. Rudge, F. Osgerby, and J. R. Eaton, of the cooperating companies who conducted the field tests and furnished valuable assistance in preparing the paper.

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Abridgment of

A Study of Telephone Line Insulators

BY L. T. WILSON*

Non-member

Synopsis.—*This paper discusses the major factors contributing to the total leakage conductance of telephone line insulators, especially at carrier frequencies up to 50,000 cycles.*

The electrical performance of three different designs is analyzed to illustrate in a general way the relative importance of the several factors.

Origin of Problem

For many years, because the frequency of the currents transmitted did not exceed about 3 kc., and because the leakage of insulators is generally low at such frequencies, the requirements of telephone insulators were relatively easy to meet.

The familiar glass insulators such as are shown in Figs. 1 and 2 therefore sufficed, the former design (d. p. type) being employed on the longer circuits and the latter (toll type) on the shorter ones. Indeed they still suffice very generally, especially where only currents of voice frequencies or less are transmitted.

The advent of carrier systems employing higher frequencies, ranging from about 3 to 30 kc., substantially changed the insulator requirements. At first these systems were few in number and relatively short in length, and the insulator problem accordingly less important.

The rapid growth of carrier systems during the past decade,[1] the longer circuits to which they have been applied, and improved standards of long-distance transmission have all been factors in increasing the requirements imposed upon the insulator and in correspondingly augmenting the importance of the problem.

It may now be remarked that the problem has been mainly one of securing economical insulators giving improved performance at these higher frequencies. In addition, the low-frequency performance of new designs had to be maintained substantially as good as that of the old designs.

Leakage Phenomena

This study has been confined almost entirely to the pin type of insulator.

When an alternating potential exists between a pair of wires at the point where those wires are supported by insulators, a current flows from one wire to the other. This current may be resolved into two components; one in phase with the potential and one in phase quadrature leading the potential.

This in-phase component, which of course represents an energy loss, is the one of chief interest here, and in using the word leakage, we refer to this component or, more accurately, to its equivalent conductance.

Of course both components in flowing through the resistance of the line conductors produce energy losses but these are so small that they will not be discussed here.

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1. See *Carrier Systems on Long Distance Telephone Lines*, H. A. Affel, C. S. Demarest, and C. W. Green, A. I. E. E. Trans., Vol. 47, 1928, p. 1360-1386.

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Except for these, all energy losses which occur due to the presence of insulators, whether they actually occur in the insulator proper or elsewhere, will be charged to insulator leakage.

It is convenient to divide insulator leakage into several sources. The division is an arbitrary one as some of the sources are not independent of each other and are difficult to separate experimentally. The division is as follows:

A-c. and d-c.	A.	Leakage directly through insulator material to pin.
	B.	Leakage directly over insulator surfaces from line conductor to pin.
A-c. only.	C.	Dielectric absorption in insulator material.
	D.	Dielectric absorption in pins.
	E.	Displacement current losses in crossarms and pins.
	F.	Losses due to unbalanced displacement currents in external resistances such as those of crossarms, poles, etc.
	G.	Displacement currents flowing over insulator surfaces through high resistance.

It should be noted that while all the items play a part in a-c. leakage, only the first two enter in the d-c. case.

The discussion of these items[2] individually, as it

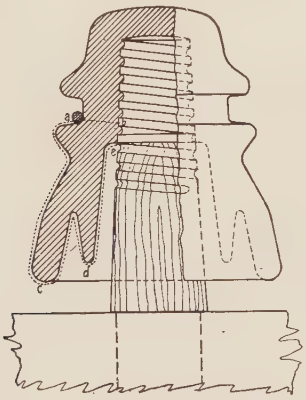

FIG. 1—STANDARD D. P. INSULATOR AND STANDARD WOOD PIN

appears in this paper in its complete form, will be here omitted. However, two new designs of insulators will be described and their performance analyzed, along with that of the d. p. type, so as to give at least a general picture of the relative magnitude of the several items.

DESCRIPTION OF NEW INSULATORS

Two new insulators are available for use on carrier circuits of the Bell System, and in cases where the additional expense of the new insulators is justified, replace the standard d. p. insulator shown in Fig. 1.

One of the new types is designed for use on the wood pins of existing lines. It is known as the c. w. insulator and its design is shown in Fig. 3. The pair of pin thimbles illustrated at the bottom of this figure is first placed over the two wood pins; then the insulators are screwed into place over the thimbles, forcing the latter well into the threads of the wood. The thimbles are constructed of thin copper and are bonded together by a tinned copper strip.

The other new type is designed to screw directly over

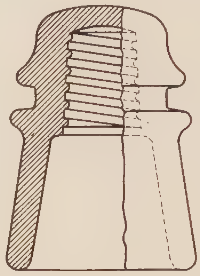

FIG. 2—STANDARD TOLL INSULATOR

a steel pin. This is known as the c. s. insulator and its design is shown in Fig. 12. At each crossarm the two steel pins are bonded by means of a wire underneath the arm.

Both new designs are molded from borosilicate glass, which is more expensive than the alkali glass used in the old d. p. design. On this account, and on account of the pin thimbles in one case and the steel pins in the other,

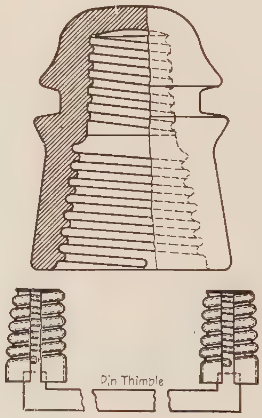

FIG. 3—STANDARD C. W. INSULATOR AND PIN THIMBLE

the new insulators cost more to install than did the old ones.

Both of the new designs were brought out several years ago before this study had conclusively demonstrated the importance of surface losses (item *G*). It will therefore be of some interest to discuss their performance in the light of the more complete knowledge.

PERFORMANCE OF D. P., C. W., AND C. S. INSULATORS

The leakage of these three types as measured on the insulator test line at Phoenixville, Pa., in a moderate rain, is given in Fig. 23, and does not represent a true

2. The existence of several of these factors appears to have been well appreciated by Mr. R. D. Mershon as early as 1908, although Mr. Mershon's measurements were made at frequencies below 100 cycles, where many of the items are extremely small in magnitude. See *High-Voltage Measurements at Niagara*, by R. D. Mershon, and *Discussion*, A. I. E. E. TRANS., Vol. 27, 1908, p. 845-929.

picture of the relative efficiency of the three types because no two of them are aged alike; besides, the relative efficiency varies considerably with different weather conditions. However, the measurement will serve our present purpose which is to analyze the total leakage of each design and thus give a perspective of the several sources of leakage. It should be pointed out and emphasized that the allocation of the total leakage to its component parts can be only very approximate.

Fig. 24 shows an estimate of the leakage contributed

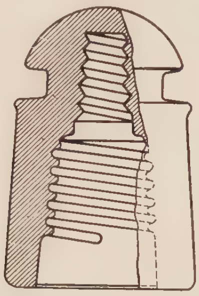

Fig. 12—Standard C. S. Design for Use With Standard Steel Pin

by the several sources for the d. p. design. The leakage directly through the insulator material is negligible, and item A therefore does not appear. Similarly, the leakage due to unbalanced displacement currents flowing in crossarms, poles, etc., is considered negligible and therefore item F does not appear.

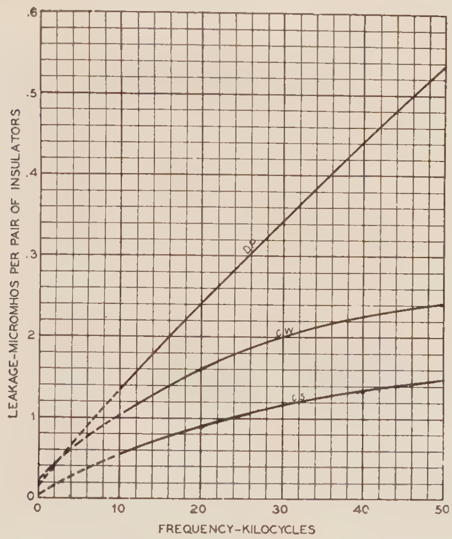

Fig. 23—Relative Leakage of D. P., C. W. and C. S. Insulators as Measured at Phoenixville, Pennsylvania, in Moderate Rain

At a frequency of 30 kc., (B, for example,) the direct surface leakage or d-c. leakage is about 5 per cent of the total. The dielectric absorption in the glass C is about 10 per cent. The dielectric absorption in the wood pins D is about 20 per cent. The crossarm losses E contribute about 10 per cent and finally, the losses on the insulator surfaces G contribute about 55 per cent.

Fig. 25 shows a similar estimate for the c. w. design. Here the bonded pin thimbles shield the wood pins from any electric field and thus eliminate dielectric absorption D from the pins. Similarly, by short-circuiting the crossarms, the losses occurring there are eliminated. Accordingly, both items D and E are made negligible and do not appear.

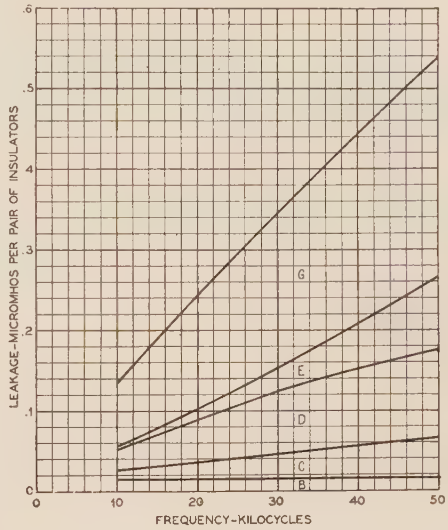

Fig. 24—Estimated Allocation of Leakage for D. P. Insulator

Of the remaining factors, the direct surface leakage B contributes about 12 per cent of the total (say, at 30 kc.) The losses in the glass C are liberally estimated at about 5 per cent. Finally, the surface losses G contribute over 80 per cent of the total.

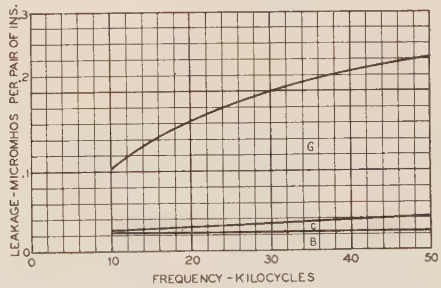

Fig. 25—Estimated Allocation of Leakage for C. W. Insulator

Comparing the c. w. performance in this test with that of the d. p., we find that most of the improvement shown by the c. w. has resulted from the elimination of items D and E. Due to the single skirt design of the c. w. and the pin thimbles, item B has been increased in magnitude. The loss in the glass C has been decreased by the use of borosilicate glass. However, the most important item G has been only slightly reduced, and if c. w. insulators in this test were aged as far as the d. p., the c. w. might show no improvement with respect to G. The pin thimble construction tends to increase the

insulator capacitance and thus make G larger for the c. w. than for the d. p. design. The use of a borosilicate glass with its lower dielectric constant counteracts this action somewhat.

The estimated division of losses for the c. s. design is given in Fig. 26. The use of metal has eliminated any dielectric absorption D from occurring in the pins. The bonding of the pins by wire has eliminated crossarm losses E.

Of the remaining factors, the direct surface leakage B contributes about 4 per cent or less of the total at 30 kc. The losses in the glass C are liberally estimated at 10 per cent or less, while the surface losses G contribute about 85 per cent or more.

In this design, the absolute magnitude of B has been decreased somewhat, chiefly because the small diameter of the steel pin permits a small diameter of insulator.

The low capacitance made possible by the small steel pin has helped to make both C and G relatively small, although most of the improvement in C is due to the borosilicate glass.

The improvement in the surface losses G over the d. p. design is quite marked.

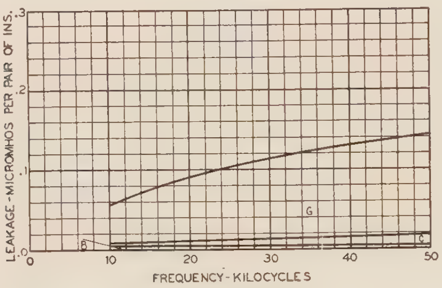

Fig. 26—Estimated Allocation of Leakage for C. S. Insulator

For the new designs, the two factors B and G are the controlling ones. In this particular test, B happens to be quite small in magnitude and would naturally lead one to conclude that it had been made unnecessarily small at the expense of G; especially since in many respects these two items place conflicting requirements on insulator design. However, B has been observed at times to reach a value as high as one-third of the total leakage at 50 kilocycles. The necessity of engineering for such cases makes the design more reasonable, especially when it is recalled that the insulators must serve for direct current and low frequencies, as well as for the carrier range.

Of the new designs, the electrical superiority of the c. s. over the c. w. design is apparent. This fact together with economic considerations has led to the almost universal choice of the c. s. rather than the c. w. type for the field of application of the new insulators in the telephone plant.

The utility of the c. s. insulators in the telephone plant will be more clearly apparent from a consideration of the reduction in attenuation which their use brings about.

The losses in transmission over a pair of wires at carrier frequencies come chiefly from two sources: one, substantially fixed in magnitude, depending mainly upon the resistance of the wires; the other, quite variable in magnitude, depending upon the leakage conductance between the wires and therefore on the weather.[3]

In the case of 165-mil copper wires on 12-in. spacing, these two components of loss are approximately equal in wet weather when the older types of insulators are used. The c. s. type cuts this variable component about in half at 30 kilocycles, thus reducing the total wet-weather attenuation of these wires to about 75 per cent of its former value. For smaller sizes of wires, the percentage reduction is correspondingly less.

The benefits of the lesser attenuation can be utilized in the plant in various ways, depending on local conditions; for example, in increasing repeater spacing, in employing smaller gages of wires, or in increasing the number of insulators per mile to provide for better transposition designs.

In addition, in having reduced the variable component of loss, the new insulators improve the stability of carrier circuits to a marked degree.

Acknowledgment

Only the electrical features of the new designs have been discussed. Closely related to these are the many mechanical problems which naturally arise in new construction. During the development of the new designs, these latter problems came under the supervision of Mr. C. S. Gordon, assisted by Mr. J. T. Lowe.

The Corning Glass Works has cooperated in molding special experimental insulators of various compositions.

Data on the electrical properties of numerous glass compositions have been supplied by the Bell Telephone Laboratories.

The writer desires to express his thanks also to Messrs. F. A. Leibe, L. R. Montfort, and L. Staehler for assistance in the measurements and to Mr. H. R. Nein for assistance in the preparation of this paper.

The total capacity of water wheels installed in water-power plants of 100 hp. or more in the United States on January 1, 1930, was 13,807,778 hp., according to the U. S. Geological Survey. This represents an increase of 236,248 hp., or 1.7 per cent, during 1929, which is unusually small, but will be in part counterbalanced by the much greater amount, about 800,000 hp., to go into operation during 1930.

Public utility plants account for 88 per cent of this total. Of the remainder, more than 60 per cent is in manufacturing and miscellaneous plants in New England and the Middle Atlantic states.—*Electrical World.*

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3. For a more detailed discussion of attenuation see a parallel paper, *The Transmission Characteristics of Open-Wire Telephone Lines*, by E. I. Green, A. I. E. E. Journal, July 1930, p. 566.

Abridgment of

The Problem of Service Security in Large Transmission Systems

BY P. ACKERMAN*

Associate, A. I. E. E.

Synopsis.—*With the rapid growth of transmission and distribution systems and the tendency to interconnect large systems, the problem of service security during abnormal conditions becomes of greatest importance.*

Service security is generally considered to be entirely a question of relay protection. This is an erroneous idea, as this paper will show that system layout and other factors are of equal importance, and that only the complete and simultaneous fulfillment of all component factors will bring the desired results.

The ultimate goal of the problem is the creation of a transmission system which is free from service interruptions. Upon first thought, this would appear attainable either by preventive measures or by protective measures.

This paper will explain briefly the impracticability of the preventive method, and will discuss the possibilities of the protective method in an endeavor to show that it is the only one promising a complete solution of the problem.

The protective method depends on the creation of a strong system in which troubles are accepted but made harmless by protective means.

The paper indicates also in a general way how such a perfect system can be created at no greater cost than present practise necessitates.

The operating results reported in the paper are all from improved existing systems, showing that here substantial improvements can be made.

* * * * *

Introduction

THE purpose of this paper is to discuss in its entirety the problem of service security of large transmission systems. This with a desire to arouse the engineer to a realization of the importance, and still more, the complexity of the problem; further to show the necessity of giving attention to this problem at the beginning of a system's growth so as to avoid disappointment or necessity of costly changes at a later stage.

The present inclination is to try to solve the security problem by avoiding trouble, applying to apparatus high safety factors, both electrical and mechanical. The success of such a protective measure depends entirely upon the strength of the system to clear troubles without inconvenience, and the purpose of this paper is to evidence the various factors essential to creating such strength.

Basic Requirements of a Strong System

System Layout. a. This must provide enough multi-supply paths between the source of power and the load distribution from any one path to be disconnected and still leave a sufficient number to carry the whole load without excessive overloading.

This is substantiated by the operating results shown in Table I, demonstrating the weakness of one-line systems, and Figs. 1 to 3 of the complete paper, and Table IV herewith, showing the strength of multi-line systems. These latter records indicate how full control over the situation is obtained while operating as a four-line system; Table II shows also the more efficient line loading of a multi-line system.

b. To avoid serious overloading of the remaining supply paths, and to prevent the loss of more than one supply path at any one moment, all paths must be arranged with physical separation sufficient to effect the segregation of faults to a single line or apparatus.

Table V shows the need of separation to avoid simultaneous lightning interference; Fig. 4, the danger of tower lines located in too great proximity to the same right-of-way. Table IV illustrates how interruptions could be entirely eliminated in a multi-line system with all circuits physically separated.

c. The system must be so arranged as to limit the collapse of the system voltage sufficiently to avoid the complete loss of the synchronizing power between composite parts of the main system in case of any kind of fault. Fig. 5 shows different system layouts which will help to uphold voltage during troubles, the arrangement in (5c) being particularly promising for trunk line systems.

d. The system layout must permit effective, instantaneous, and complete protection.

e. By the natural system reactance, it must limit the short-circuit current in any part of the system to a magnitude which is within the safety limits of available circuit breakers.

System Protection. This comprises circuit-breaker and the relay equipment which plays the important role of clearing faults and must therefore be rendered practically infallible by meeting the following requirement:

a. The breakers must be capable of handling any short-circuit current within its reach and under maximum short-circuit conditions. The mechanism must be simple and easily maintained, with the total tripping time as short as possible.

Station diagrams providing a multi-switch path for each apparatus and affording easy overhauling facilities for switching equipment must be supplied.

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*Consulting Elec. Engr., for Shawinigan Water & Power Co., Montreal, and Hydro-Electric Power Commission of Ontario, Toronto.

Presented at the Summer Convention of the A. I. E. E., Toronto, Ontario, Canada, June 23-27, 1930. Complete copy upon request.

TABLE I
OPERATING RECORDS OF ONE-LINE SYSTEMS

Nature of trouble	a. 180-*Kv. Isle Maligne-Quebec Line* (Shawinigan Water & Power Co.) D-c. Street tower line with vertical conductor arrangement with middle conductor on extended crossarm. One circuit only in service. 10-disk suspension string. Two overhead ground wires. Length—130 mi.				b. 230-*Kv. Gatineau-Toronto Line* (Hydro-Electric Power Commission of Ontario) S. C. St. Tower with horizontal conductor arrangement. 18-disk suspension strings. Two overhead ground wires. Length—230 miles.	
	1928		1929		Oct. 1928/March 1, 1930	
	Transient troubles	Permanent troubles	Transient troubles	Permanent troubles	Transient troubles	Permanent troubles
Lightning	2		5		4	
Sleet and wind	..		3			
Trees and branches	..				2	1*
Broken ground wire	..	4*	..			
Broken klydonograph wire	..				1	
Misc. and unknown	1		4			
Total number	3	4	12	..	7	1
Outage	½ hr.	28 hr.	2¾ hr.	..	3 hr.	10 hr.
Total number of troubles per year	7		12		8	
Total outage per year	28½ hr.		2¾ hr.		13 hr.	
	*Caused by vibration trouble during first few months of operation until remedied				*Occurred during first month of operation before clearing of right-of-way was completed	

Note: Both these systems are only operated temporarily as *one-line* systems, as a first step to a *multi-line* system.

TABLE II
RELATIVE CAPACITY OF MULTI-LINE SYSTEMS
100 per cent = Max. Permissible Load of One Circuit

System	Total max. permissible system load	Normal condition all circuits in service load/circuit	Emergency Condition one circuit disabled. load per circuit: Per cent of max. circuit load	Multiple or normal circuit load
Two-line system	100%	50%/circ.	100%/circ.	2 x N.
Three-line system	200%	66%/circ.	100%/circ.	1.5 x N.
Four-line system	300%	75%/circ.	100%/circ.	1.33 x N.

b. The whole primary relay system must be able to clear selectively any faulty apparatus or line without causing interruption to the load.

To avoid the need of removal on a ground fault, the generators are operated with isolated neutral. The station diagrams must permit segregation of the generator should a ground fault occur. Fig. 11A shows permanently separated generators on the low-voltage side. Fig. 11B gives a diagram in which the low-voltage side is normally operated in parallel but which permits segregation of the low-voltage side should a ground fault occur.

TABLE IV
ANALYSIS OF CAUSES AND RELATIVE FREQUENCY OF SHUT-DOWNS FROM SHORT CIRCUITS, AND THEIR REMEDY

Records covering period	a. 110-*Kv. Suspension Line* (S. W. & P. Co.)[1] two D-C. Circuits—80 mi. 1923-1929		b. *90-Kv. Pin Type Line* (T. P. Co.)[2] one D-C. Line—80 mi. 1916-1924		Remarks
	No.	Per cent	No.	Per cent	
1. Single-line short circuits cleared selectively and without causing interruption while operating on Multi-line System	112	88	285	75	Shutdown was avoided in all cases by multi-line system
2. Short circuits causing shutdowns. a. While operating on one line only	..	..	45	12	Shutdown could have been avoided by multi-line system
b. Lightning striking all circuits	3	2	40	10.5	Shutdown could have been avoided by separation of circuits
c. Miscellaneous short circuits affecting all lines simultaneously	13	10	9	2.5	Shutdown could have been avoided in almost all cases, by separation of circuits
Total line short circuits	128	100	379	100	
	1. Shawinigan Water & Power Co.		2. Toronto Power Co. now owned and operated by Hydro-Electric Power Commission of Ontario		

TABLE V
GENERAL NATURE OF LINE TROUBLES

Records covering period	a. *110-Kv. Suspension Line* S. W. & P. Co.[1] two D-c. circuits, 80 mi.		b. *90-Kv. Pin Type Line* T. P. Co.[1] 1-D. C. line, 80 mi.	
	1922-1929		1919-1924	
	Number	Per cent	Number	Per cent
Total number of line short circuits of which............	142	100	292	100
1. *Transient Troubles*, that is, line available immediately after short circuit had been cleared....................	120	85	262	90
2. *Permanent Troubles*, disabling line until repaired:— a. Permanent primary troubles....................	22	15	23	7½
b. Power-arc damage..........................	..		7	2½
	1. Shawinigan Water & Power Co.		2. Toronto Power Co. now owned and operated by Hydro-Electric Power Commission of Ontario.	

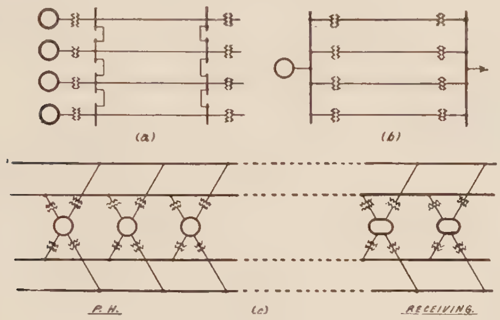


FIG. 5—SCHEMATIC BASIC SYSTEM DIAGRAMS

(a) Network system
(b) Trunk line system with transformers inserted thus obtaining metallically separated high-voltage trunk lines
(c) Trunk line system with metallically separated high-voltage trunk lines, acting as system busses

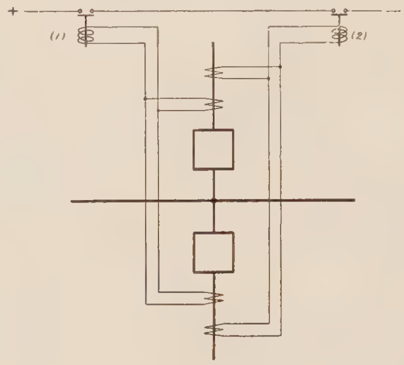


FIG. 16—SCHEMATIC DIAGRAM OF DUPLICATE PROTECTION

Case illustrated on a duplicate differential current-protection
2 sets of identical protective features are provided with trip contacts arranged in series to each other, so that only joint action of the two features will effect the tripping of the circuit breaker

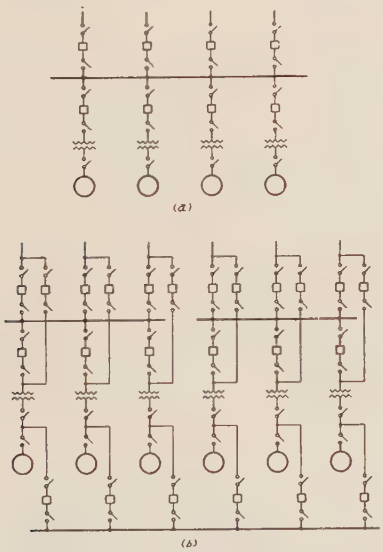


FIG. 11—SCHEMATIC POWERHOUSE DIAGRAM TO PERMIT OPERATION WITH ISOLATED GENERATOR NEUTRAL

(a) Units permanently separated on low-voltage side
(b) Units connectable to a low-voltage parallel bus, the latter to act as tie bus between subsystems
Units can be operated separated on low-voltage side if wanted

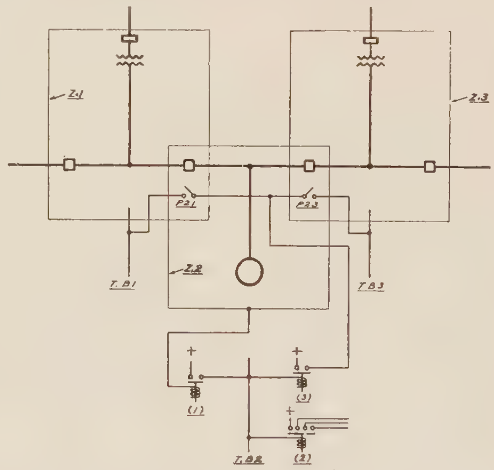


FIG. 17—SCHEMATIC DIAGRAM OF EMERGENCY TRIP (SHOWN FOR ZONE 2)

(1) Diff. relay of $Z.2$
(2) Trip relay of $Z.2$
(3) 0.6 Sec. definite time emergency trip relay
T. B. 1 trip bus $Z.1$
T. B. 2 trip bus $Z.2$
T. B. 3 trip bus $Z.3$
*P.*12 and *P.*23 Pallet switches on circuit breakers. Closed with the breaker closed and opened with the breaker open

Functioning of the Emergency Trip:

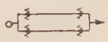
Assume a fault in zone 2 causing the diff. relay (1) to trip, energizing the trip bus *T.B.*2 and trip relay (2), which latter is to trip all breakers of *Z.*2. If the trouble does not clear because of one of the breakers not opening, the *D.T.* relay (3) closes contacts 0.6 sec. after the trip bus *T.B.* 2 has been energized. The closing of relay (3) makes alive the trip bus of the adjacent zone through the pallet switch of the switch which remained closed, thus tripping the breakers of the adjacent zone, thus completely clearing the faulty Zone 2

c. The clearance must take place in the shortest possible time so as to have the least effect on the system stability; also to eliminate power-arc damage in case of flashover, and reduce the hazard of station fires in case of transformer and oil-switch failures.

TABLE VI

STABILITY OF T. P. CO'S.[1] SYSTEM (25-CYCLE) UNDER TRANSIENT CONDITIONS

Operating experience regarding load loss due to line short circuits cleared by protection.
(Approx. 50 per cent synchronous load; frequency changers and rotaries)

Reference No. to columns	1			2						3					
				(a)			(b)			(a)			(b)		
Period of operation...	1914/16 three years			1916/18 three years						1919/23 five years			1924 one year		
Operating voltage....	60,000 volts delta			60,000 volts delta						90,000 volts Star with solidly grounded neutral			90,000 volts		
Protective device.....	Nicholson's arc extinguisher			Parallel-line protection			Double-line protection			Double line protection					
Operating diagram....										 Separated on h. v. side during lightning with trf. neutral isolated			 Parallel on h. v. side at all times with solidly grounded trf. neutral		
Duration of short circuits..........	Total clearing time: 0.4 to 0.6 sec. (All shorts were power-house bus short circuits)			Total clearing time: (a) For middle line shorts circuits—0.25 sec. (b) For line end short circuits—0.50 sec. of which 0.25 sec. low voltage 0.25 sec. voltage partially recovered						Total clearing time same as for Column 2					
No. of short circuits accompanied by the following load losses:	No.	Per cent		No.	Per cent		No.	Per cent		No.	Per cent		No.	Per cent	
0—5% load loss....	6	26	44	28	88	94	40	76	92	93	52	82	4	12	41
5—15% load loss....	4	18		2	6		9	16		53	30		10	29	
15—30% load loss....	..	..		..	..		2	4		21	12		13	38	
30—50% load loss....	3	13	56	1	3	6	..	..	8	9	5	18	2	6	59
50—100% load loss...	10	43		1	3		2	4		2	1		5	15	
Total short circuits cleared without interruption.............	23		100	32		100	53		100	178		100	34		100

1. Toronto Power Co. now owned and operated by Hydro-Electric Power Commission of Ontario.

Table VI indicates how, with quick-acting protection, power-arc damage in case of transmission line flashovers can be completely eliminated. This results in a very great improvement since 85 to 90 per cent of all line troubles are with flashovers.

Station troubles are similarly cared for, with 60 to 80 per cent in this case being harmless flashovers leaving no damage, whereas in the cases of apparatus breakdown, the damage is localized and the fire hazard almost eliminated. Over 50 station short circuits have been cleared by instantaneous protection without a single case of station damage.

d. The relay schemes and settings applied to the various apparatus must respond to any conceivable kind of trouble, whether internal in the apparatus or at a terminal. Further, it must be effective under any operating condition; that is, at times of maximum as well as under minimum connected generator capacity.

f. Precautionary features such as standby protection, duplicate protection, and emergency trip, must be provided to act as second line defense. Fig. 16 shows schematically the principle of duplicate protection as applied to a differential current feature, to avoid wrong tripping in case of secondary trouble in the current transformer circuit. Fig. 17 shows in like manner, the emergency trip which is to clear the adjacent zone should a circuit breaker fail to open.

g. To be effective, a maintenance staff must be educated to the task of looking after the whole protective equipment, including breaker and relay equipment, eliminating every possibility of failure caused by inherent weakness in the protective equipment. This is absolutely necessary in order to avoid so far as possible the necessity of the standby protection to save the situation.

Conclusion

A system laid out in accordance with the basic requirements discussed in this paper should approach 100 per cent service security at all times. If full advantage is taken of the new conditions created by such a system, (which accepts short circuits as a matter of course and without danger to the system), it should be possible to build one at equal or even less cost than the system arranged in accordance with present day practise, and with the added advantage of corresponding economy.

Abridgment of

Lightning Investigation on 220-Kv. System of the Pennsylvania Power & Light Company (1928 and 1929)

BY NICOLAS N. SMELOFF[1] and A. L. PRICE[2]

Associate, A. I. E. E. Associate, A. I. E. E.

Synopsis.—*The purpose of this paper is to describe the results of a lightning investigation conducted during 1928 and 1929 on 114 circuit miles of a 220-kv. system located in a territory where severe lightning storms are frequent. During the 1929 investigation, which was a continuation and expansion of previous years' work, a number of devices was successfully used, such as surge voltage recorders, cathode ray oscillographs, electric field intensity recorders, and lightning stroke recorders. Some of these devices are new.*

Many valuable data on magnitude and wave shape of actual lightning surges were obtained, proof of the existence of both single- and multiple-phase faults due to lightning; some data on the shielding effect of overhead ground wires, and qualitative data on the nature and time of discharge of lightning strokes together with the atmospheric gradients resulting therefrom, were also obtained.

General Review

INVESTIGATIONS of lightning with particular reference to its effect on the transmission line and associated station apparatus comprising the 220-kv. system of the Pennsylvania Power & Light Company have been in progress since 1926. Data obtained in 1926 and 1927 are available in a paper[3] presented before the A. I. E. E. in 1928.

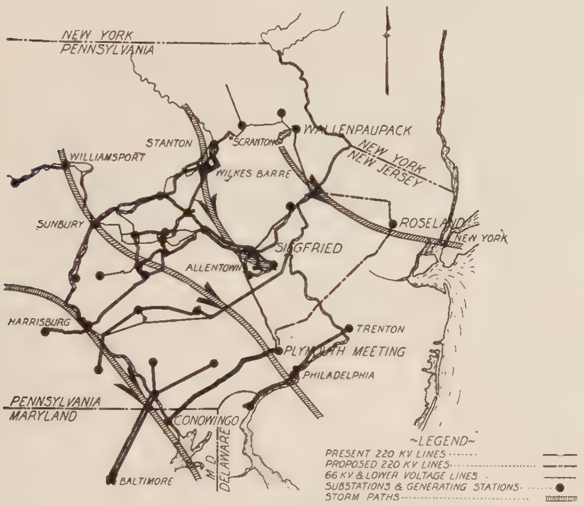


Fig. 1—System Diagram and Weather Map

Line Data

The 220-kv. system of the Pennsylvania Power & Light Company consists of the Wallenpaupack-Siegfried and Plymouth-Siegfried lines. These lines, together with future interconnections, are shown in Fig. 1.

General characteristics of the Wallenpaupack-Siegfried line were published in the previous paper.[3] Early in 1929, a so-called "counterpoise" was installed for a distance of about 2½ mi. along a section of the line where flashed insulators had been particularly numerous (see Fig. 18). This counterpoise was a buried No. 00 copper cable, which connected the tower footings. In addition to the counterpoise, the insulator assemblies on the outside conductors during the 1929 lightning season were increased from 14 to 16 units over the 40-mi. section of the line adjacent to Wallenpaupack.

Facilities

This investigation was conducted, and facilities were made available cooperatively by the General Electric Company and the Pennsylvania Power & Light Company. The Public Service Electric and Gas Company of New Jersey and the Philadelphia Electric Company cooperated in supplying lightning weather data and in the general analysis of all data obtained. The Philadelphia Electric Company also supplied operating data on its section of the Plymouth-Siegfried line.

Apparatus employed and the scope of the investigation are indicated in Table I.

TABLE I
MEASURING DEVICES AND FACILITIES

	No. of instruments	
A—Instruments used on Lines	1928	1929
Cathode ray oscillograph[4]	1	1
Surge voltage recorders[5]	39*	28
Lightning stroke recorders[6] on towers	0	284
High-speed phase current recording ammeters	0	6
B—Instruments Coupled to Antennas		
Cathode ray oscillograph	0	1
Surge voltage recorders	7	12
C—Weather Data		
Weather observations from operating stations	29	160
Weather observations including location of lightning strokes, from Fire Towers and Wallenpaupack Lightning Laboratory	1	4
Radio set weather indicator at Wallenpaupack Lightning Laboratory	0	1
Electric field intensity recorder[6]	0	1
Rate of change of field recorder[6]	0	1
D—Operating Data		
Overhead (tower climbing) patrols—Wlpk.-Sieg. Line	5	20
Siegfried-Plymouth Line	2	3
Operating records from 220-kv. operating stations		

*Excludes 6 surge voltage recorders used for measurement of wave shape and duration of surge voltages.

Lightning Weather Data

Lightning weather observations were secured from approximately 160 observation points in the operating territories of all the power companies in a district from Altoona east to New York and from Wallenpaupack

1. System Planning Engineer, Pennsylvania Power & Light Co., Allentown, Pa.

2. General Engineering Laboratory, General Electric Company, Schenectady, N. Y.

3. For all references see Bibliography.

Presented at the Winter Convention of the A. I. E. E., New York, N. Y., January 27-31, 1930. Complete copy upon request.

south to Washington, in addition to reports from the lightning laboratory. Typical storm paths are shown in Fig. 1, indicating the storm paths followed on June 19, 1929. Generally, the storms move from west to east or from northwest to east southeast.

Results

Cathode Ray Oscillograms. The first oscillogram of lightning surge was obtained in 1928 and has been previously described.[7]

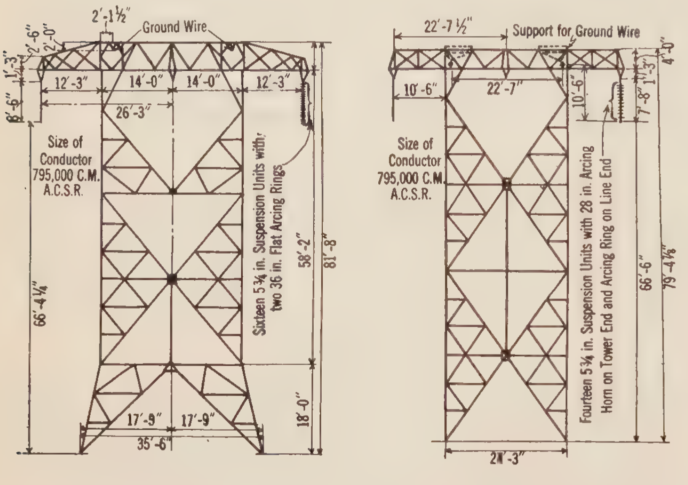


Fig. 2—Standard Type "A" Suspension Towers

During the 1929 lightning season, cathode ray oscillograms of 95 voltage surges on phase *Y* of the Wallenpaupack-Siegfried line were obtained at the lightning laboratory at Tower 1-3, and 11 cathode ray oscillograms were obtained of voltage surges on the antenna at the lightning laboratory.

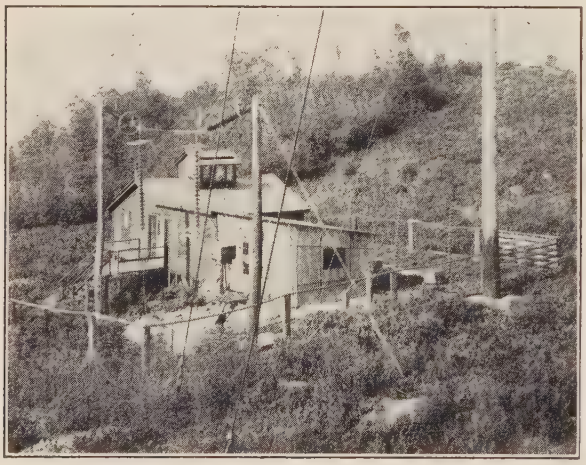


Fig. 4—Photograph of Wallenpaupack Lightning Laboratory

Of the 95 oscillograms obtained of voltage surges on the line, 50 measured under 100 kv. at the cathode ray oscillograph, 30 measured between 100 and 300 kv., and 15 measured above 300 kv. The cathode ray oscillograph connections allowed measurements of voltages superimpsoed on the normal 60-cycle wave, while the surge-voltage recorders measured total voltage to ground.

The wave shapes of the 15 surges above 300 kv. and that of the surge obtained in 1928 have been classified into three groups. These are shown in Figs. 6, 7, and 8 respectively.

Group 1—Fig. 6. The general characteristics of the wave shapes shown in this group are those common throughout all the oscillograms obtained. These waves rise to 75 per cent of crest-voltage value in from 2 to 5 microseconds, reach crest value in 3 to 11 microseconds, decrease to 50 per cent crest value in 14 to 20 microseconds and pass through zero in 18 to 30 microseconds. After passing through zero, these surges rise to a low value of voltage of opposite polarity to that of the first loop and maintain this low voltage until the end of the record, 45 to 90 microseconds. The first loop of the voltage surges in this group is of positive polarity.

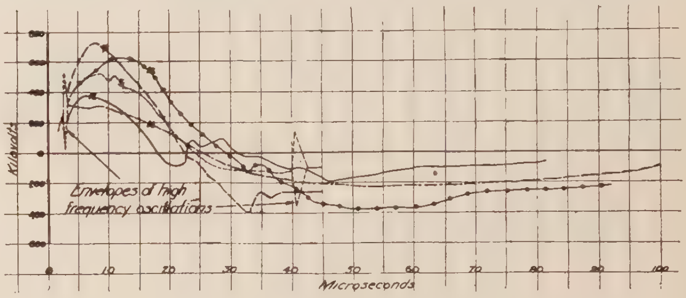


Fig. 6—Wave Shapes of Lightning Surges—Group 1

Group 2—Fig. 7. Wave shapes 1 and 2 in this group are affected by the arc-over of the insulation nearby, and for this reason have characteristics not noted in other waves. Wave fronts range from 1.6 to 8 microseconds and duration of first loops from 29 to more than 50 microseconds. In general, the wave fronts rise more rapidly and the wave tails decrease in voltage more slowly than wave shapes in Group 1.

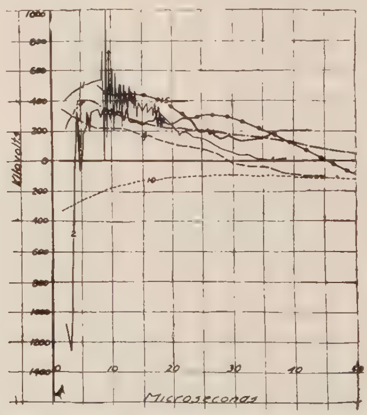


Fig. 7—Wave Shapes of Lightning Surges—Group 2

Group 3—Fig. 8. Wave shapes in this group are of a composite nature in that they have more than one peak value without a polarity reversal. A rather long period (at least 30 or 40 microseconds) of high sustained voltage results from this double-peaked characteristic. Negative polarity predominates in this group.

The actual oscillograms of one surge from each of these groups are shown in Figs. 9, 10, and 11 respectively.

Summary of Cathode Ray Oscillograms of Transmission Line Surges. Voltages reach 75 per cent of their crest in an interval of time ranging from less than 1.0 to 36 microseconds, then 100 per cent of crest value in 1.2 or less to 82 microseconds, decrease to 50 per cent of crest value in 3.7 to 156 microseconds, and reach zero of the first loop in 4 to 156 microseconds; 50 per cent of surges reach at least 75 per cent of their value in less than 3 microseconds.

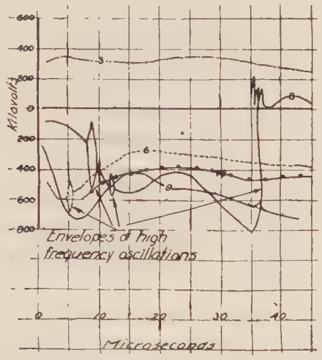


Fig. 8—Wave Shapes of Lightning Surges—Group 3

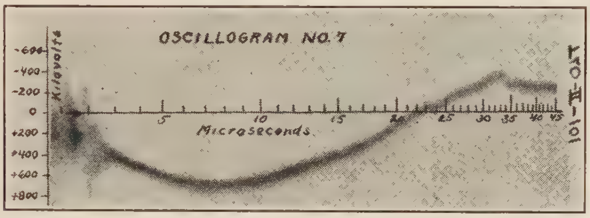


Fig. 9—Oscillogram of Lightning Surge—Wave Shape 7 of Group 1, Fig. 6

A majority of the surges have a wave front of 3 to 8 microseconds and a duration of the first loop of 15 to 40 microseconds. Approximately 70 per cent are positive in polarity and 30 per cent negative for the first loop. Within the time range of the oscillograms, approximately 60 per cent are slightly oscillatory and 40 per cent unidirectional.

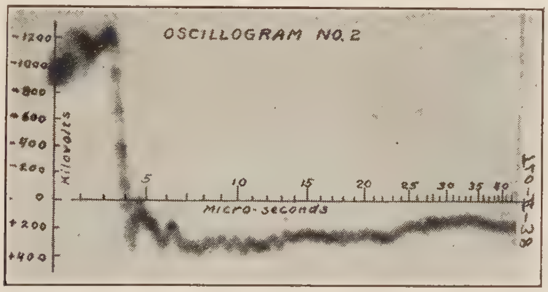


Fig. 10—Oscillogram of Lightning Surge—Wave Shape 2 of Group 2, Fig. 7

Surge-Voltage Recorder Data

Fig. 14 shows that about 50 per cent of the lightning surges on the Wallenpaupack-Siegfried line and 15 per cent of those on the Plymouth-Siegfried line were above five times normal. (900 kv.)

While voltages of about 2400 kv. were registered on both lines, not all of the high voltages were coincident with trip-outs. This is shown in Fig. 15.

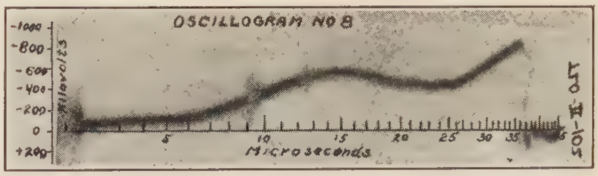


Fig. 11—Oscillogram of Lightning Surge—Wave Shape 8 of Group 3, Fig. 8

Antennas

Data obtained from the antennas were not numerous but are important.

One complete record was obtained at the laboratory at 2:33 p. m., on June 19, 1929, when a surge was measured on all antennas at the lightning laboratory. The results are shown plotted in Fig. 17. The voltage on the 50-ft. antenna under the ground wire was about one-half that on the 50-ft. antenna not protected with ground wire. Voltage on the transmission line at the lightning laboratory was less than 300 kv.

At this time a voltage gradient of 53 per foot was indicated by the storm intensity recorder, the storm clouds being directly over the lightning laboratory with lightning strokes occurring as near as one-half mile.

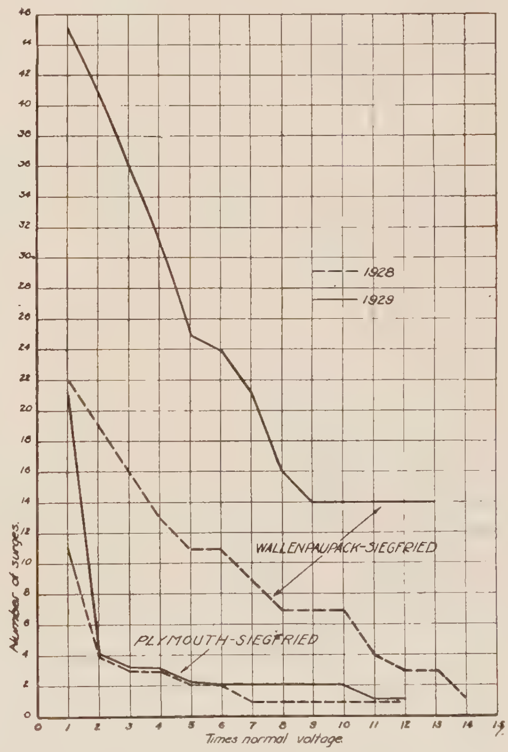


Fig. 14—Number and Crest Value of Lightning Surges

Direct Strokes

Lightning stroke recorders indicated two direct strokes. At tower 40-2 the current as estimated from the lightning stroke recorder registrations was

Fig. 15—Number and Crest Value of Lightning Surges on Wallenpaupack-Siegfried Line

Showing relation of surge voltages to circuit trip-outs

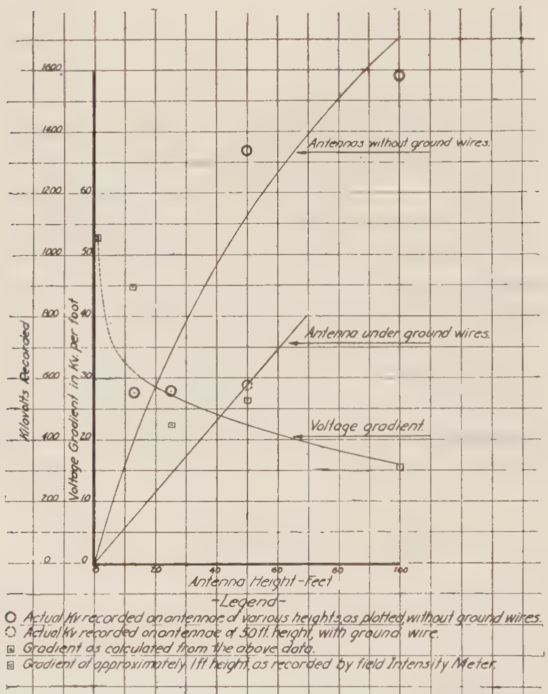


Fig. 17—Voltages on Antennas—Surge No. 23

60,000 amperes, and was due to a negative cloud discharge to ground.

At tower 12-5 on a portion of the line where the counterpoise was installed, a negative cloud discharge of about 100,000 amperes was indicated.

During the 1929 lightning season, 24 cloud-to-ground strokes were observed within a one mile radius of the Wallenpaupack lightning laboratory, none of which are known to have hit the transmission line.

Conclusions

1. Records obtained from storm reports show that in general storms cross this system from west to east or from northwest to east southeast.

2. Wave fronts of lightning surges recorded on the transmission line have a range from a fraction of a microsecond to 82 microseconds. A common characteristic was a front between 3 and 8 microseconds, a duration of the first loop of 15 to 40 microseconds, and of a slightly oscillatory nature. Positive polarities predominate.

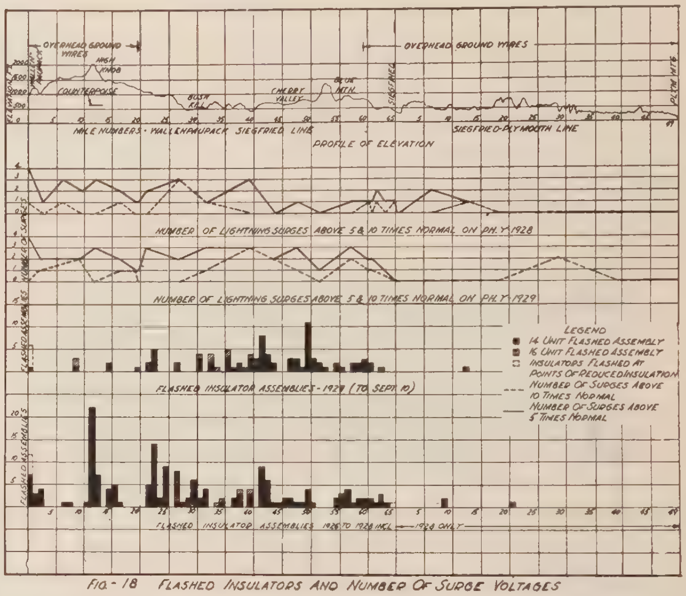


FIG-18 FLASHED INSULATORS AND NUMBER OF SURGE VOLTAGES

Fig. 18—Flashed Insulators and Number of Surge Voltages

3. Not all high voltages are accompanied by trip-outs of the circuit.

4. Lightning surges may be unidirectional (either polarity high) or slightly oscillatory.

5. Surge voltages of positive polarity attenuate more rapidly than those of negative polarity.

6. The quantitative value of protection afforded by overhead ground wires cannot be deduced from the limited data. One record on antennas indicates a protection of about 50 per cent against induced voltages.

7. Preliminary data indicate that high voltages due to direct strokes having currents of over 100,000 amperes are infrequent.

8. An average of from 3 to 5 insulator assemblies were flashed per trip-out of the circuit and about 70 per cent of these showed glaze burns by dynamic arcs. Most of the flashed assemblies were on the outside phases.

9. A considerable percentage of trip-outs are due to multiphase faults.

ACKNOWLEDGMENTS

Acknowledgments is made to Messrs. E. Bell, E. A. Evans, G. J. Gross, H. B. Newsom, N. Rohats, and others[10] for field work, analysis, and correlation of data, and to Messrs. C. M. Foust, C. A. Jordan, E. S. Lee, W. W. Lewis, H. S. Phelps, H. K. Sels, and A. E. Silver for general direction of this investigation.

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Abridgment of

A General Switching Plan for Telephone Toll Service

BY H. S. OSBORNE*

Fellow, A. I. E. E.

Synopsis.—*This paper outlines a comprehensive plan for improved switching of long haul toll telephone traffic in the United States and eastern Canada. A brief discussion is given of the methods of designing the toll plant to give adequate transmission efficiency for all connections established in accordance with this plan. This includes a new method of providing amplification at intermediate switching points replacing the cord circuit repeater method.*

ON January 25, 1915, with due ceremony, telephone service was inaugurated between the Atlantic and Pacific Coasts. This occasion marked a great step forward both technically and commercially. Before that time, the limit of practicable telephone transmission had been about 1500 mi. The transcontinental service was made possible by the completion of numerous important developments, particularly the perfection of telephone repeaters and means for applying them to long wire circuits.

Until then, the Pacific and neighboring States had been isolated telephonically from the eastern and midwestern parts of the country. The demonstration of commercially practicable telephone circuits across the continent gave great impetus to the idea of universal service; that is, the provision of a telephone plant to give service between any two telephones in the country at commercially attractive rates.

In the fifteen years since the opening of the first transcontinental circuits, the ideal of universal service has been realized to a large extent. Practically all the telephones of the United States and a large part of Canada now have provision for connection with the countrywide toll telephone network, more than 99 per cent being included. Achieving universal service, however, involves a great deal more; circuits must be provided in such numbers and so arranged that connections between any two telephones can be established quickly and without too many intermediate switching points. Also the telephone plant must be so designed for such standards of transmission that these connections when established will permit satisfactory conversation.

Associated with this development of the telephone plant has been the very rapid increase in traffic. A striking characteristic of this growth is that the increase has been much more rapid for the longest lengths of haul than for the shorter lengths of haul. For example, during the last five years, in which the messages on lengths of haul up to 250 mi. were approximately doubled, the messages on hauls from 250 to 1000 mi. increased five times, and those over 1000 mi. increased more than ten times. This characteristic is also illustrated in Fig. 4 which shows the growth in the number of direct circuits from New York and Chicago to the Pacific Coast, averaging about 2500 mi. in length. This particularly rapid growth in very long haul traffic has made it practicable to establish a considerable number of long haul circuit groups and has greatly assisted in the problem of satisfactorily handling calls between widely separated points. It has led to the condition in which today 74 per cent of the long distance (long lines) messages are handled over direct circuits, and 20 per cent, with one intermediate switch.

The part of the business on which it is most difficult

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Presented at the Summer Convention of the A. I. E. E., Toronto, Ont., Canada, June 23-27, 1930. Complete copy upon request.

to give high grade service is naturally the scattering business between widely separated points. In these cases, each item of traffic—that is, the business between two specific points—is relatively small, but the number of items of traffic is great. The number of messages involved in each item of traffic does not justify direct circuits and in a very large number of cases, in order to

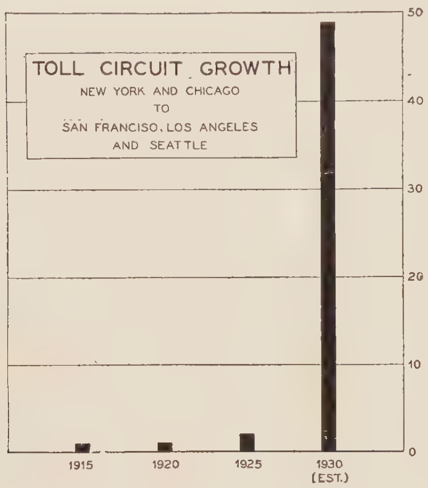

Fig. 4

provide a connection, it is necessary to make more than one intermediate switch. This at present applies to 6 per cent of the long distance telephone business of the country. All measures of the quality of service—speed, accuracy, and transmission—show that the difficulty of handling the service satisfactorily increases rapidly with the number of intermediate switches involved.

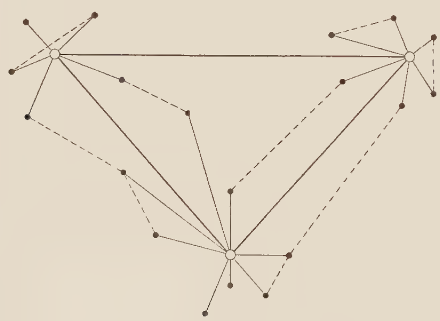

Fig. 5—General Toll Switching Plan Application in Local Company Area

Solid Lines—Fundamental routes of general plan
Dashed lines—Supplementary direct-circuit groups
○ Primary outlet
● Toll center

General Toll Switching Plan

The conditions outlined above form the background which has made it both important and possible to adopt a new fundamental arrangement in the layout of toll plant and the routing of toll messages. This is called the "general toll switching plan," and its purpose is to provide systematically a basic plant layout designed for the highest practicable standards of service consistent with economy, including speed, accuracy, and directness of routing between any two points in the country, and suitable transmission standards. This involves the laying out of the plant in such a manner as to limit as much as practicable the number of switches required to provide connection between any two telephones, and the establishment of standards of design and construction to provide satisfactory transmission over any route thus operated. The plan is therefore of particular value in improving the service conditions of switched toll traffic; that is, traffic requiring the connection of two or more toll circuits.

The general features of the plan will be understood by reference to Figs. 5 and 6. Fig. 5 shows the application of the plan to a limited operating area such, for example, as a state. Within the area is selected a small number of important switching points designated as "primary outlets." Each toll center is connected directly to at least one of these outlets, and all primary outlets within the area are directly interconnected. This makes possible the interconnection of any two toll centers within

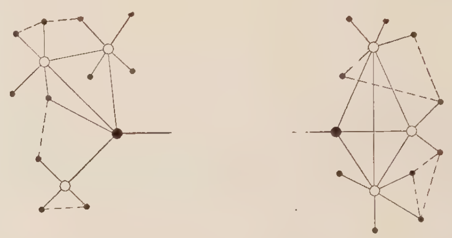

Fig. 6—Illustration of Interconnection of Important Switching Offices Throughout Bell System

Solid lines—Fundamental routes of general plan
Dashed lines—Supplementary direct-circuit groups
● Regional center
○ Primary outlet
● Toll center

the area with a maximum of two switches, and within the part of the area served by one primary outlet with a maximum of one intermediate switch.

The primary outlets were selected after a careful study of the present switching and operating conditions and the probable development of toll traffic within the various areas, with a view to obtaining the minimum number of primary outlets capable of handling the traffic economically. The routings provided by the plan are supplemented by direct circuits or by other routings where the amount of business justifies such additional circuits as indicated by the dash lines in Fig. 5.

It is interesting to note that it is found practicable to take care of switching for the 2500 toll centers of the United States and eastern Canada by the establishment of approximately 150 of these as primary outlets.

For handling the business throughout the country, eight of the primary outlets are designated as "regional centers." The method of routing calls is indicated by Fig. 6. Each primary outlet is connected with at least

one regional center and with as many more as practicable. Each regional center is directly connected to every other regional center in the country. By this means, any one of the primary outlets, which are the 150 most important switching centers in the country, can be connected to any other primary outlet in the country with a maximum of two switches and, within the area served by a regional center, with a maximum of one intermediate switch.

The extent to which intermediate switching is limited by the application of this plan is indicated by Table I which shows the maximum number of switches required under the plan between different types of toll centers. It is estimated that by means of this plan, the percentage of long haul messages requiring more than one intermediate switch will be reduced more than 50 per cent.

Where the amount of business is sufficient to make this economical, the routes provided by the plan for countrywide service are also supplemented by more direct routes of equivalent or better service characteristics. Furthermore, in some cases the routes to regional centers are supplemented by alternate routes through what are called "secondary outlets." These are distinguished from the primary outlets in that they do not necessarily have direct-circuit connections to all toll centers in their areas, but serve a useful purpose as an alternate route for the toll centers connected to them.

The essential features of the general toll switching plan from the standpoint of the interconnection of the switching offices may be summarized as follows:

Regional Centers. Regional centers are switching offices strategically located to cover the various parts of the country and completely interconnected with direct circuits, thus forming the basis of a countrywide toll network.

Primary Outlets. Primary outlets are switching offices having direct circuits to one or more regional centers and each having direct circuits to all toll centers in the area for which it is the primary outlet. Also, each primary outlet is connected to every other outlet within as large an area as practicable, usually within a State.

Supplementary Offices. (a) Secondary Outlet. Secondary outlets are switching offices having direct circuits to one or more regional centers and are intended primarily to furnish alternate routes for toll centers for reaching the regional centers, thus providing a greater degree of flexibility in the plant. (b) Secondary Switching Points. Secondary switching points are additional switching offices intended to provide routes which are more direct, thus reducing back haul for intra-area business.

TABLE I
GENERAL TOLL SWITCHING PLAN
Maximum Number of Switches

	Same Regional Area				Another Regional Area			
To— / From	Regional center	Primary outlet	Toll center directly connected to regional center	Toll center directly connected to primary outlet	Regional center	Primary outlet	Toll center directly connected to regional center	Toll center directly connected to primary outlet
Regional center	0	0	0	1	0	1	1	2
Primary outlet	0	1	1	2	1	2	2	3
Toll center (directly connected to regional center)	0	1	1	2	1	2	2	3
Toll center (directly connected to primary outlet)	1	2	2	3	2	3	3	4

Transmission Considerations of General Toll Switching Plan

An important part of the development of the plan was the determination of proper transmission requirements so that any toll connection established in accordance with the plan would have satisfactory transmission efficiency.

The general use of repeaters has removed the limitation formerly set by circuit attenuation, and has made possible the increase in the efficiency of circuits to the limit determined by some other characteristic of the circuit. There are various things which under different conditions may determine this limit: One is the effect of echoes on transmission; namely, portions of the speech currents reflected back from the distant end of the circuit or from intermediate points. Another is the distortion due to the building up of transmission gain greater at certain frequencies than at others, which effect may result if repeaters introduce too great an amplification into the circuit. As an extreme case, this might result in a sustained oscillation or singing on the circuit. Other effects which may be important are those of crosstalk between telephone circuits, or of noise induced in the telephone circuits from outside sources, both of which are increased by increasing repeater gains. On the longer connections, echoes are almost always the controlling factor, whereas on the shorter connections, such effects as crosstalk, singing, and noise generally are limiting. A reduction in any of these effects generally involves more expensive types of construction.

The difference between the attenuation loss of the circuit and the total transmission gain introduced into

the circuit by repeaters is spoken of as the net equivalent. For long telephone circuits, it is generally economical to provide repeater gain sufficient for the circuit to be operated at the minimum net equivalent permissible, this minimum equivalent being determined by the transmission factors just mentioned. Therefore, in establishing satisfactory transmission efficiencies for the over-all toll connections in accordance with the toll switching plan, each link must be designed on the basis of the minimum working net equivalent which it will contribute to an over-all connection made up of several circuits switched together.

The establishment of satisfactory and economical transmission requirements for the toll circuits laid out in accordance with the plan involves the following steps: (a) The establishment of satisfactory over-all net transmission equivalents. (b) The coordinated design of all classes of toll circuits and subscribers' circuits, toll switching trunks, and tributary trunks connected to them, so that when suitable transmission gains are provided by repeaters in the toll circuits and at toll switching points, desired over-all transmission standards will be given at a minimum total cost. (c) The economical and satisfactory distribution of transmission gain, permitting all toll circuits to be operated at their minimum net equivalents when this is desirable.

The over-all transmission equivalents to be given under the plan are based on standards which heretofore have been used for a large part of the toll business, but which it has been impracticable to meet in many cases between widely separated points. With the means now available for operating circuits at their minimum working net equivalents, it was found that satisfactory over-all transmission equivalents could be provided under the plan even for the maximum number of switches using standards for the construction of toll circuits, very comparable with those already applied to new circuits. Expressed in terms of the transmission reference standard, the plan set up gives a maximum of 25-db. over-all equivalent within one interconnected area (two intermediate switches) and a maximum of 31 db. between any two telephones in the United States and eastern Canada.

In order to determine the most economical distribution of these over-all equivalents, a study was made based upon the estimated total number of toll circuits of each class in 1932 and their distribution by length. It is also necessary to include the corresponding estimates for the plant between the toll office and the subscriber, the loss in this part of the plant being on the average about half of the over-all net equivalent of the connection. Based upon these estimates, it was possible to determine by an economic study the distribution of the over-all minimum net equivalent between these various parts of the circuit which would give minimum total expenses. The toll terminal losses and the minimum net equivalents for toll circuits established in this way are shown in Table II.

Provision of Transmission Gain at Intermediate Switching Points

The third step, previously mentioned, is the determination of the best distribution of repeater gains to permit the individual circuit to be operated by itself or in conjunction with other toll circuits at approximately the minimum net equivalent as determined by the several effects mentioned previously.

When a toll circuit is switched to another toll circuit, the over-all combination in general can be operated at a lower net equivalent (as determined by echo effects) than the sum of the two circuits when operated individually, in which case, the minimum equivalent is determined by the crosstalk, singing, and noise effects. Therefore in the case of connections built up by connecting together a number of toll circuits, it is necessary to introduce repeater gain at the intermediate switching points.

In the past, the use of cord circuit repeaters has been an outstanding element in the provision of improved

TABLE II
GENERAL TOLL SWITCHING PLAN
Transmission Design Data

Classification of toll circuit involved	Minimum working net loss of toll circuit—db.	Maximum via operating equivalent—db.	Transmission margin—db.
Toll center to primary outlet	3.0	4.0	+1.0
Toll center to regional center	3.5	4.0	+0.5
Primary outlet to regional center	3.5	3.0	−0 5
Regional center to regional center	4.0	3.0	−1.0*
Primary outlet to primary outlet	4.0	3.0	−1.0
Toll center to toll center	6.0	6.0	..
Direct toll circuit (for terminal use only)	9.0	..	..
Toll terminal loss	7.0	.	..

*Circuits equipped with echo suppressors may be designed with greater negative margins.

transmission on switched connections. It has, however, some disadvantages which have increased in importance with the increase in transmission efficiency of circuits and with the rapid development of toll business. The routine for inserting the cord circuit repeaters when needed is necessarily somewhat cumbersome, involving considerable expense for operators' labor and for increased use of the toll circuits by operators. Furthermore, under practical conditions it was found to be impossible to insure that the cord circuit repeaters would always be used when required by the routing instructions.

Recent developments in the types of toll circuit have greatly increased the numbers of toll circuits provided

with repeaters at their terminals as a part of the most economical circuit design. When such repeaters are available, the desired switching gain can be obtained by making use of the gain available in these repeaters. The great increase in the number of terminal repeaters required for other reasons, important reductions in the cost of repeaters, and the savings of operators' labor and circuit time, have made it practicable to adopt a plan of providing at certain points terminal repeaters for every circuit, thus doing away entirely with cord circuit repeaters at these points. With the terminal repeater arrangement, the insertion of transmission gain on switched connections is done automatically by taking out of each circuit on such connections a section of artificial line; this is of course the equivalent of increasing the gain of the terminal repeater.

Satisfactory transmission results for all connections under the general toll switching plan involve the insertion of repeater gain on all connections switched at important switching points. This will be carried out by the terminal repeater plan just described. The design of each circuit must of course be such that when either end of the circuit is connected to a subscriber's station, the repeater gain at that end will not be greater than permissible under the terminating condition; but that when two or more of such circuits are connected together for a long built-up toll connection, the complete circuit will operate at as nearly as practicable its minimum working net equivalent.

Programming the Establishment of the General Toll Switching Plan

The full application of the general toll switching plan involves a large number of individual rearrangements of plant layout; the establishment of certain new circuit groups and the rerouting of a considerable amount of switched business, the conversion of the switching offices to the terminal repeater arrangement, and the modification of the transmission requirements of certain of the circuits. These changes will be carried out as required by the normal growth and development of the business. The existence of a comprehensive plan of this sort insures that the program of rearrangements as carried out will be along the lines of greatest economy and maximum improvement in service.

Future View

Such a plan as has just been discussed is naturally not a static thing but is subject to continual modification to bring it into correspondence with changed conditions. In connection with such changes it is of interest to consider briefly the probable long time trend of the development of the plan.

One possible ultimate development would be the increasing connection of primary outlets to a single regional center so that ultimately only one regional center would be necessary, thus reducing the number of switches to three. If this were to take place, the regional center would undoubtedly be Chicago.

It seems evident, however, that such a plan would have many disadvantages; with such an arrangement, to avoid uneconomical back-haul of large amounts of traffic, numerous secondary regional centers would be necessary, and the economies of such an arrangement do not look promising. Furthermore, it would lead to a tremendous congestion of through switching at one point, such congestion extending far beyond the limits of economical concentration, and leading to serious operating difficulties.

A second and, it is believed, more promising general trend would result from the gradual increase in the number of regional centers as the continued development of business makes this economical. With this growth would come also a continued increase in the number of toll centers connected directly to a regional center. By this process there would be a continued growth in the number of toll centers which can be interconnected with a maximum of two intermediate switches, and it is possible that ultimately, the primary outlets can drop out of the picture completely, giving a maximum of two intermediate switches for the entire country. While any such outcome is evidently many years away, it seems probable that it is along these lines the growth in development of the plan should be directed.

Although this direction of development avoids the congestion which would be brought about by the single regional center plan, even under this plan the rapidly growing amount of toll switching to be done in large metropolitan centers offers a very important problem for the future. Toll switching at these points is rapidly outgrowing the capacity of a single manual switchboard, as the switching of local calls did long ago. Equipment changes are being made which increase this capacity, but they can be but a temporary relief. Looking to the future, an increasing amount of the outgoing traffic will be handled by operators in the local central offices, reaching the toll line over toll tandem trunks. It is evident, however, that the ultimate solution of the problem will involve the use of machine methods for the selection of the toll line by the operators, as is now done in certain segregated toll tandem systems.

The entire trend of recent years is thus to decrease the differences between the handling of exchange messages and of toll messages. At the present time more than 95 per cent of the toll messages are completed while the subscriber remains at the telephone, with speeds of completion only slightly slower than those of exchange messages. Transmission standards, while naturally somewhat better for the shorter distances involved in exchange messages, are nevertheless rapidly becoming very comparable. The present view of trends for the future is for continuation of this process, perhaps even to the use of similar types of machine equipment at central offices for switching the various classes of messages.

Abridgment of

Critique of Ground Wire Theory

BY L. V. BEWLEY*

Associate, A. I. E. E.

Synopsis.—The complete paper consists of three parts; I—Induced Potentials, II—Direct Hits, and III—Other Effects. The work of previous investigators is briefly reviewed, and the limitations of their premises pointed out. Under Part I, a generalized theory of ideal ground wires is offered, taking into account the law of cloud discharge, the distribution of bound charge, and the formation of traveling waves. It is found that the protective ratio is independent of these factors. A more extensive theory taking the additional factors of successive reflections and tower resistance into account is then developed. Part II discusses the probability of a line's being hit, and applies a method for computing the effect of successive reflections to the calculation of potentials on the line and ground wires. Curves of these potentials at successive towers and as functions of tower resistances and of time, are given. Part III discusses the effect of ground wires on attenuation, telephone interference, zero-phase sequence reactance, corona, and the reduction in surge impedance due to the introduction of extra ground wires. There are three mathematical appendixes. In Appendix I, Maxwell's electrostatic and electromagnetic coefficients are reviewed and the theory of traveling waves on any number of parallel wires, including the behavior of these waves at rather general transition points developed. While this extension to the theory of traveling waves was developed incidental to the study of ground wire theory, it is believed to be of considerable interest and value on its own account. Appendixes II and III are the mathematical analyses corresponding to Parts I and II, respectively.

I. Induced Potentials

Review of Previous Investigations. When a charged cloud approaches a transmission line, charges of opposite sign leak over the insulators or migrate from the line terminals and appear on the line and ground wires as bound charges fixed in position by the electrostatic field of the cloud. The distribution $f(x)$ of any bound charge is proportional to the electric field G, but the actual magnitudes of charge on the several conductors depend upon their sizes, heights, and arrangements. These geometric factors are uniquely accounted for by Maxwell's coefficients, as described in Appendix I. Now when the field collapses according to some law $F(t)$ of cloud discharge, the bound charges on the line and ground wires are released and form pairs of traveling waves moving in opposite directions away from the center of disturbance. The process and methematical laws by which these waves form and develop have been given in a previous paper.[1] The waves which originated on the ground wires reach the tower where they suffer partial reflections and refractions, the extent of which depends upon the relative values of the surge impedances of the circuits and the tower resistance. However, unless the cloud discharge is instantaneous, diminishing residual bound charges remain on the line and ground wires until the cloud discharge is completed.

The conventional method for calculating the protective ratio (defined as the ratio of the voltage on a line wire with ground wire protection, to the voltage which would exist without ground wire protection) is based on the tacit assumptions that (a) the ground wires are "ideal,"—that is, perfectly grounded throughout their length,—(b) the cloud discharge is instantaneous, (c) traveling waves are not formed, and (d) the distribution of bound charge is uniform.

The published theoretical work which has been done with ground wires grounded through resistances,[2,3] has also been confined to the case of rectangular bound charges instantaneously released, and subject to the further restrictions of a single ground wire and a single line wire, although the possibility of introducing an equivalent ground wire and an equivalent line wire was erroneously supposed. Moreover, reflections were limited to a single span.

Peek[4] has made extensive tests on models to ascertain the protective ratio for numerous different arrangements of ground and line wires. Some of his results are given in Table I (complete paper). Of course with tests made in a laboratory, there is no room on the model transmission line for the development of traveling waves, and the conditions are inherently static. However, as will be shown, for ideal ground wires the protective ratio is independent of the formation of traveling waves.

Peek's tests show consistently lower protective ratios than those computed by the conventional method. Hunter[5] has attempted to account for this discrepancy as due to the formation of corona, resulting in an enlargement in the effective size of the conductor, and a corresponding reduction of induced potential.

McEachron, Hemstreet, and Rudge[6] have studied the ground wire effect with traveling waves, and have ingeniously separated the total effect into two parts; first, the reduction in voltage due to the escape to ground of the bound charge on the ground wire; and second, the further reduction in voltage due to the acquisition of a charge of opposite sign by the ground wires. Their results are in excellent agreement with calculations of the protective ratio by the conventional method. As the potentials of the impressed waves were relatively low corona did not enter into the picture.

A number of measurements with antennas has been taken in an effort to obtain field data on the protective

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1. For references see Bibliography.

Presented at the Pacific Coast Convention of the A. I. E. E., Portland, Oregon, Sept. 2-5, 1930. Complete copy upon request.

ratio afforded by ground wires. Smeloff and Price[7] mention one record in which a protective ratio of approximately 50 per cent was indicated. Here again there is no room for the formation of traveling waves, and the situation is inherently static. The indicated protective ratio is of the order of that calculated by the conventional method,—certainly within the range of accuracy of the measurements.

From the foregoing review of the work that has been done on induced strokes, it is evident that no single study has explicitly included all of the essential factors involved, nor has any definite effort been made to correlate the different methods of attack on the problem, so as to prove their equivalence. It is not entirely obvious, for example, that the same protective ratio would be found in the case of tests with traveling waves (a strictly dynamic situation) as are calculated by the conventional method based on purely static equilibrium conditions. It is still less obvious that either of these methods gives the same protective ratio as obtained under actual conditions. Table II outlines the assumptions underlying the several methods of attack, and serves to indicate their limitations from the point of view of rigorous analysis. It is partly the purpose of this paper to correlate these separate investigations by contributing a generalized theory of ideal ground wires, and an extension to the theory of periodic resistance grounds.

TABLE II
INVESTIGATIONS OF GROUND WIRE PROTECTION FOR INDUCED VOLTAGES

		Considered the effect of:											
	Method	Distribution of bound charge	Law of cloud discharge	Residual charges	Formation of traveling waves	Developed traveling waves	Corona	Tower resistance	No of spans	Successive reflections	No. of ground wires	No. of line Wires	Remarks
THEORETICAL	Conventional (Petersen)	No	No	Yes	No	No	No	No	No	No	Any	Any	
	Hunter	No	No	Yes	No	No	Yes	No	No	No	Any	Any	
	Cox & Slepian	No	No	No	No	Yes	No	Yes	No	No	One	Erroneously	Approximate attenuation
	Fortescue, Atherton, & Cox	No	No	No	No	Yes	No	Yes	No	On one span	One	Erroneously	Approx. for the mutual induction
	Ideal ground wires (this paper)	Yes	Yes	Yes	Yes	Yes	Hunter's	No	No	No	Any	Any	
	Periodic resistance grounds (This paper)	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Any	Any	
TESTS	On Models—Peek	No	Yes	Yes	No	No	Yes	No	No	No	Any	Any	
	Antennas	No	Yes	Yes	No	No	Yes	Yes	No	No	One	One	Unsatisfactory
	Traveling Waves—McEachron	No	No	No	No	Yes	Yes	Yes	Partly	Partly	Any	Any	Equal waves on all wires

Ideal Ground Wires. In Appendix II of the complete paper, the general theory of ideal ground wires (ground wires perfectly grounded at all points) is worked out. The analysis includes the effects of the law of cloud discharge, the distribution of bound charge, the formation and development of traveling waves, and residual charges. It is applicable to systems having any number of ground and line wires, and Hunter's correction for the effects of corona can be applied in the same way as to the conventional method of calculation.

Now the amazing conclusion reached as a result of this analysis is that the protective ratio (in the case of ideal ground wires) is independent of the law of cloud discharge, of the distribution of bound charges, and of traveling waves, and is exactly the same expression as that found by the conventional method of calculation. In other words, the same protective ratio would be found by any method for which ideal ground wire conditions prevail, and these include;

1. The conventional method (and Hunter's correction).
2. Tests on model transmission lines (Peek).
3. Tests with traveling waves (McEachron).
4. Measurements on antennas.

Of course, the actual voltages induced on a line are quite different depending on the law of cloud discharge, etc., but the *percentage* reduction in voltage to be realized by the employment of ground wires is independent of these factors.

Appendix II therefore establishes the validity for obtaining the protective ratio by any of the several different methods. In addition, Appendix II offers a means for computing the actual voltage induced on a line.

Periodic Resistance Grounds. The essential elements of the theory of periodic resistance grounds have already

been given by Cox and Slepian.[2] It remains to extend the theory to include the effects of the law of cloud discharge, of the distribution of bound charge, and of a multiplicity of reflections from successive spans, and to take into account properly the presence of any number of line and ground wires. The generalization will then be complete.

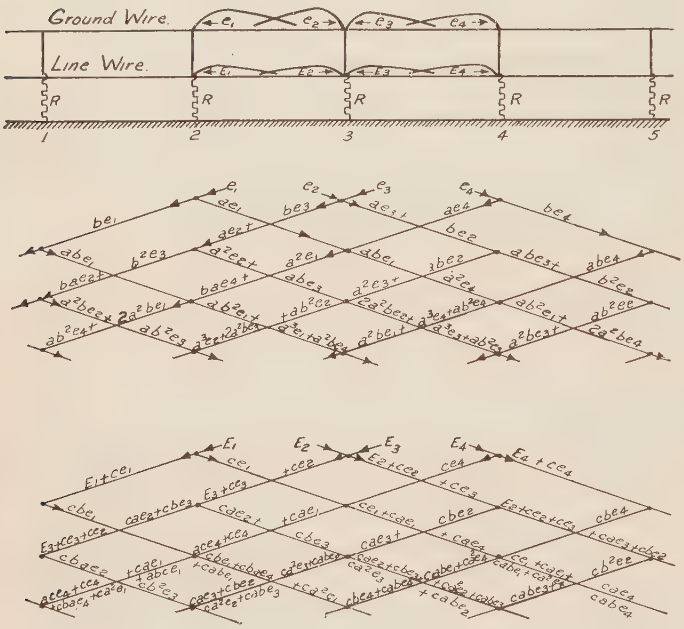

FIG. 5—WAVES FROM RELEASED BOUND CHARGES

Top lattice: Reflections and refractions on ground wire
Bottom lattice: Reflections and refractions on line wire

The steps in the complete solution are as follows:

(A) Replace the actual ground wires by an equivalent ground wire consistent with the conditions imposed by Equations (38) to (41), Appendix I.

(B) Consider each span between towers separately and for each span compute the traveling waves on every wire. Then

$f_1 = \phi(t) \, . \, h_1 G$ = *incident wave on ground wire.*

$f_2 = \phi(t) \, . \, h_2 G$ = *incident wave on line wire.*

where h_1 and h_2 are the heights of the wires, G is the field gradient, and $\phi(t)$ is a function involving the bound charge distribution $f(x)$ on the span and the law of cloud discharge $F(t)$. It may be evaluated by any of the graphical, tabular, or analytic methods given in *Traveling Waves Due to Lightning.*[1] It is simply the function expressing the shape of the wave issuing from the bound charge distribution.

(C) Calculate the reflection and refraction operators for both the line and ground wires as given by Equations (3), (4), (5), and (6) of Appendix III. Then

$F_1 = a f_1$ = *reflected wave on ground wire*

$f_1'' = b f_1$ = *transmitted wave on ground wire*

$F_2 = c f_1$ = *reflected wave on line wire*

$f_2'' = f_2 + c f_1$ = *transmitted wave on line wire.*

(D) Construct a lattice as shown in Fig. 5, of a sufficient number of sections to include the requisite time interval and number of spans, and therefrom determine the potentials at all points by superposition.

The simplest case is that of an instantaneous cloud discharge and rectangular bound charges. This also gives the maximum departure of the potential at mid span with respect to that at the tower. Curves calculated on this assumption for a bound charge 2000 ft. long and with 1000-ft. spans are shown in Fig. 6.

II. DIRECT HITS

In Fig. 7B are plotted a set of curves showing the distance D, corresponding to $r = H$, between the projection of the approaching center of disturbance and the tower, as a function of the cloud height H and the tower height h. If there is absolute certainty that lightning will strike within a zone of width W centered on the transmission line, then the probability that the line will receive the stroke is $2\,D/W$. When it is realized from the curves of Fig. 7B that the susceptible zone $2\,D$ is of the order of 1000 ft., it is not surprising that lines are hit. If the tower is on the top of a hill or ridge (as is so often the case in order to provide for long spans) then the chance of being hit is greatly magnified.

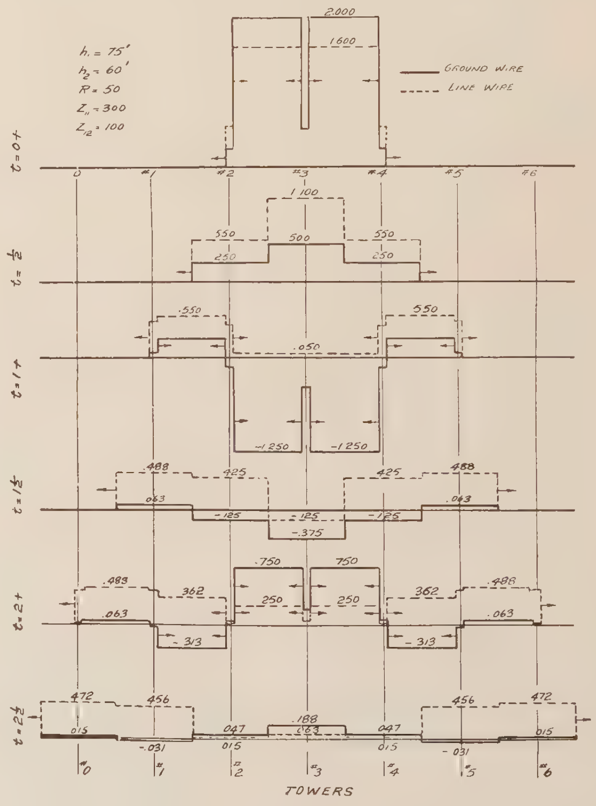

FIG. 6—APPROACH TO IDEAL GROUND WIRE CONDITIONS ON THE SPANS

The susceptible distance $2\,D$ can only be ascertained in such a case by drawing the clearance arc as shown in Fig. 7C. The tower is more likely to be struck than the span because it is higher than the sagging span and also because the towers usually occupy the high points along the right of way.

Fig. 11 illustrates the effect of resistance on the ground and line wire potentials, and the difference in

potential between line and ground wires. Fig. 12 shows the voltages as functions of time at three adjacent towers, and includes the effects of successive reflections from all adjacent towers.

In general, there are four distinct and definite advantages to low ground resistances:

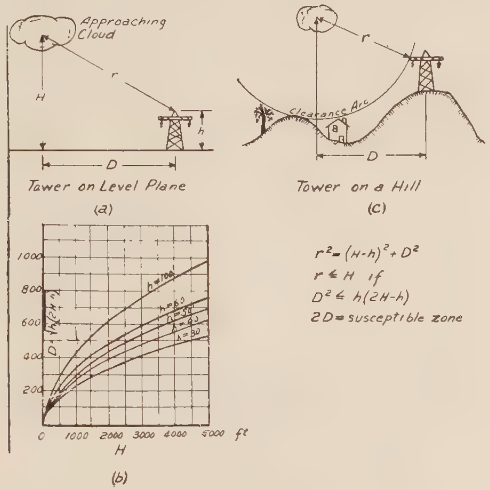

FIG. 7—PROBABILITY OF A LINE'S BEING HIT

1. Reduced potential on the ground wires at the tower.
2. Reduced potential on the line wires at the tower.
3. Reduced potential between line and ground wires.
4. Limitation of dangerous potentials to fewer spans.

Peek has advocated the use of one ground wire, called the direct-hit wire, sufficiently higher than the other conductors to make them fall inside its protec-

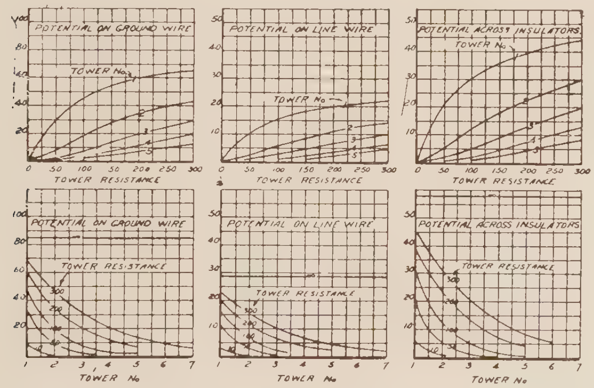

FIG. 11—POTENTIALS AT THE TOWERS IN PER CENT OF THE LIGHTNING VOLTAGE

tive wedge. Other ground wires may be used in conjunction with it to limit the potentials caused by induced strokes. Unless the direct-hit wire is placed sufficiently high such an arrangement does not obviate the possibility of side flashes taking place from the direct-hit wire to the other conductors; nor is it an unmitigated advantage to increase the height of the direct-hit wire beyond that necessary to avoid side flashes, for a higher wire not only invites more strikes, but also increases the voltage between the line and ground wires, so that the potential across the insulator string is increased. Curves illustrating these conditions are shown in Fig. 13 for strikes at the tower and at mid span. The basis of comparison is the lightning voltage defined as the potential of a hypothetical freely traveling

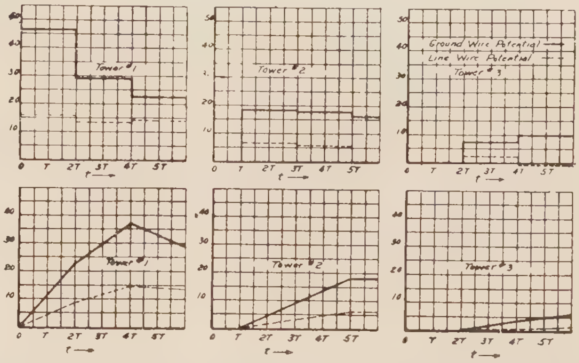

FIG. 12—POTENTIALS AT THE TOWERS AS FUNCTIONS OF TIME

Top: Infinite rectangular applied wave
Bottom: Infinite flat-top wave with 4 T front

wave descending the lightning bolt of surge impedance Z_0. (Method of analysis described in complete paper). Two scales for the ordinates are given in Fig. 13, a percentage scale which is valid for all lightning voltages, and a voltage scale based on a lightning voltage of

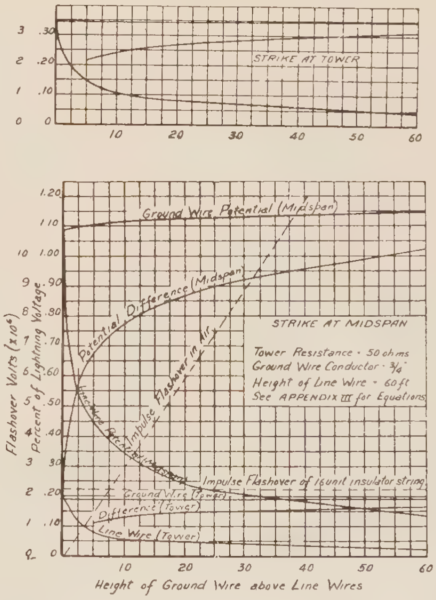

FIG. 13—EFFECT OF INCREASING THE HEIGHT OF THE GROUND WIRE

10×10^6 volts. This is probably as severe a stroke as any for which design would be feasible.

In designing a line for a maximum lightning voltage of 10×10^6 it is evident from Fig. 13 that the direct-hit wire must be elevated 35 ft. above the line wires at mid span to insure that there will be no side flash to them. The requisite number of insulators at the towers depend

upon the ground resistance and may be decreased when good grounds are obtained, or else carry a greater margin of safety. Fig. 13 shows curves corresponding to a ground resistance of 50 ohms. Too much emphasis cannot be laid on the advantage of decreasing the tower resistance, as was illustrated in Fig. 11. For resistances of the order of 10 ohms the reduction in voltage is practically proportional to the tower resistance; that is, a 5-ohm tower resistance means only half the voltage of a 10-ohm tower resistance.

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Abridgment of

Effects of Lightning Voltages on Rotating Machines and Methods of Protecting Against Them

BY F. D. FIELDER[1] and EDWARD BECK[1]

Associate, A. I. E. E. Member, A. I. E. E.

Synopsis.—*Rotating machines directly connected to overhead lines are subject to damage from lightning surges. Many methods of protection against such damage are possible and several of them are discussed in this paper. Laboratory experiments have been made to show the normal distribution under various steepnesses of waves, and the improvement of unsatisfactory distributions by means of condensers or lightning arresters connected to various parts of the windings has been studied.*

THE purpose of this paper is to discuss means of protecting from damage by lightning voltages, rotating machines directly connected to overhead lines. A study of the distribution of surge voltages in the windings of machines under various conditions was made and is described.

The Problem

Two problems are involved; one, the limitation of the surge voltages which may be impressed on the insulation between the windings and ground, and the other, the limitation of the voltage impressed on the insulation between turns to a safe value. The voltage impressed between windings and ground depends principally upon the magnitude of the transient voltage which reaches the machine; the voltage impressed between turns of the winding depends on both the magnitude and wave front of the incoming transient and the distributed capacity and inductance of the winding. Protection of a machine against these voltages can be accomplished by several methods which will be discussed later in the paper.

Present Practise

No special pains have been taken in the past to protect rotating machines directly connected to overhead lines although it is generally recognized that it is more difficult to protect them against damage by a surge voltage than a transformer since, because of physical limitations, the insulation used in generators or motors is not so resistant to impulse voltage. It is usually recommended that rotating machines be connected to overhead lines through the medium of an insulating transformer, but when this is not done, the problem of protecting the machine becomes of importance.

The principal danger is the breakdown of insulation between turns because of non-uniform voltage distribution. The voltages which will exist across the insulation between turns is determined by the crest voltage of the applied surge, by the length of time it takes to reach a crest value, and by the constants of the winding circuit. It is therefore possible that although the magnitude of the incoming surge is limited by an arrester to a value sufficiently small to prevent damage to the insulation to ground, the wave front of the surge may be steep enough to cause such a voltage distribution in the machine winding that the insulation between certain turns may be overstressed and damaged. While the magnitude of these voltages between turns is also dependent upon the magnitude of the surge voltage permitted to enter the machine, a reduction in this surge voltage will reduce the stresses in the winding. For this reason, it has been recommended that in applying arresters to machines directly connected to overhead lines, those of the lowest possible rating should be

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1. Both of the Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

Presented at the Summer Convention of the A. I. E. E., Toronto, Ont., Can., June 23-27, 1930. Complete copy upon request.

applied in order that the surge voltage may be limited to the greatest possible extent. Rather than risk damage to the machine, it has been thought desirable to run the risk of an occasional arrester failure due to unbalanced or runaway voltages. On the whole, this practise has shown satisfactory results, but it is subject to improvement by arranging more uniform distribution of voltage in the winding.

When the surge voltage first enters the machine, the potentials developed across various parts of the winding

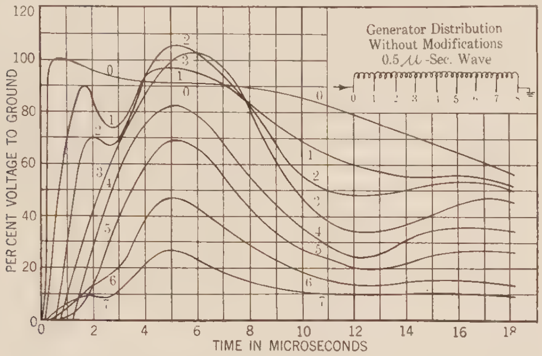

Fig. 2—Voltage—Time Records Obtained on Unmodified Winding, with ½-Microsecond Wave

are determined by the electrostatic field conditions of the winding. As the surge penetrates farther into the winding, these conditions change, as will also the voltage conditions. When the surge first enters the winding, a considerable portion of the total voltage may appear across certain turns or coils.

Experimental Tests

In order to investigate the potentials to which machine windings may be subjected when surges of various shapes enter, a series of tests was made on a commercial rotating machine in the High-Voltage Laboratory at Trafford City. These tests were on a standard 5000-kv-a., 4000-volt, three-phase, 60-cycle, 900-rev. per min. synchronous condenser, which had two parallel groups of windings per phase, each group containing eight coils with five turns per coil. Well insulated taps were brought out from each coil; surges of various wave fronts were applied to the windings and cathode ray oscillograms were obtained of each test. The method of the test and the test circuit used are described in greater detail in the complete paper.

Two waves were used for most of the tests; one was a wave with a rapid rise which increased from zero to crest value in one-half microsecond; the other rose to crest value in approximately two microseconds. In the light of recent data on the shapes of actual lightning surges, it appears that the wave fronts of the majority of lightning surges which reach apparatus is not so steep as the wave fronts of those applied in these tests; hence the tests, particularly those made with the ½ microsecond wave front, probably represent more severe conditions than will ever be experienced in practise. To show further the effect of the change in equivalent frequency, a third wave was applied to the unmodified winding. This wave rose to crest value in 12 microseconds. To show comparative results which hold for any applied voltage, curves were plotted on a percentage basis of voltage-to-ground. Actually, the wave used had a maximum value of 6300 volts. All waves decreased from crest value to an average of 60 per cent after 20 microseconds with the generator connected.

Unmodified Distribution

The first problem was to determine the voltage distribution throughout the unmodified winding for the various waves under consideration. Fig. 2 shows the replotted oscillograms for the ½-microsecond wave. The worst stress occurs across the first coil shortly after the wave strikes the winding, and amounts to 80 per cent of the applied voltage. This stress is rapidly relieved, for only 0.2 of a microsecond later, it has been reduced to 60 per cent. One microsecond after the application of the surge, the stress across the first coil becomes 30 per cent. The greatest voltage to ground is obtained after approximately five microseconds, and amounts to 106 per cent of the impressed voltage. It occurs between the second and third coils from the line end.

The effect of a considerably slower wave rising to crest value in 12 microseconds was studied. It will be seen that the stresses are comparatively small, in no case exceeding a maximum of 20 per cent across any individual coil.

The point to which the modification of the wave must be carried for a satisfactory distribution depends upon the natural frequency of the generator, for if the impressed wave has an equivalent frequency less than the

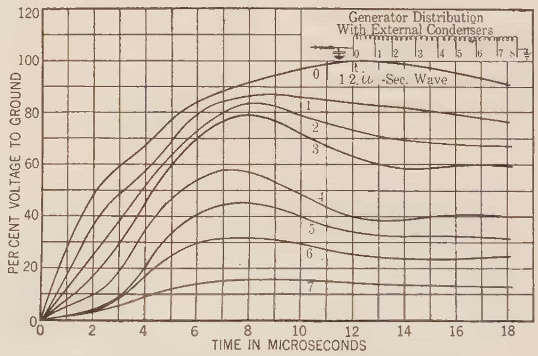

Fig. 7—Voltage—Time Records Obtained on Unmodified Winding with 12-Microsecond Wave

natural frequency of the machine, little distortion of the distribution is possible.

Distribution Modified by Distributed Capacitors

In accordance with theory it follows that the addition of small capacities connected to points in the winding would improve the voltage distribution obtained with steep fronts.

Fig. 10 shows the results obtained with the ½-microsecond wave and these condensers. The curves show

that with a maximum stress of less than 25 per cent on any coil at any time, and voltage to ground always less than the applied surge, high-voltage concentrations have been eliminated.

Protection against Uneven Distribution by Means of Shunt Lightning Arrester Units

In this case, small arrester units were placed across the coils having the greater stresses, thus limiting the voltage to less than a dangerous value. As the voltage across the first coil reaches the breakdown value of the

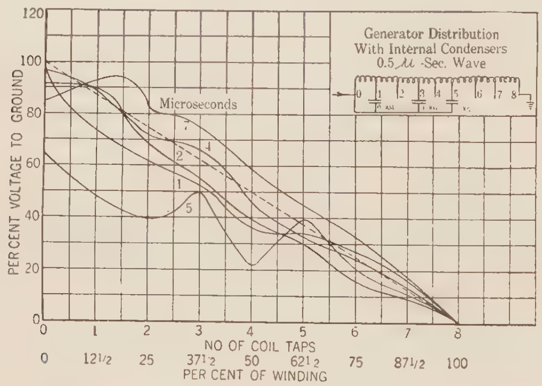

Fig. 10—Replot of Oscillograms, Winding Equipped with Internal Condensers, with ½-Microsecond Wave

arrester, the arrester will operate, absorb a portion of the energy of the wave, and pass the remainder on to the second coil. An arrester across the second coil will operate in the same way; and so on, until the surge is completely distributed. The greatest stresses were only slightly above 20 per cent. With the 2-microsecond wave, similar results were obtained. On the whole, those obtained with the lightning arresters were as good as those with the internal condensers, and show stresses and voltage to ground of approximately the same values.

The tests described in the foregoing show that the voltage distribution in the machine windings can be made practically uniform by several methods.

I. Changing the Shape of the Applied Wave

As indicated by theory and shown by tests, if the front of the applied surge has a sufficiently gradual rise, the voltage distribution in the winding will be quite uniform. The incoming wave front can be sloped off to the required degree by the insertion of inductance or capacity or both in the lines to the machine. The front and the crest of the incoming surge can be controlled by such protective equipment together with a lightning arrester. This is discussed in some detail in the complete paper.

II. The Use of Cable Between the Machine and the Overhead Line

It is well known that cables will exert considerable effect on surges penetrating them from overhead lines. This effect depends upon the relative surge impedances of the overhead line and the cable and the length of the cable. It is questionable whether cables of the length generally used have sufficient protective effect to safeguard a machine against lightning damage, particularly since the relatively low voltage lines usually involved are generally over insulated or supported on wood poles so that their flashover voltages are high and the magnitudes of the surges which can pour voltage into the cable therefore great.

III. Condensers Tapped to Points of the Winding

As was to be expected from theory, the tests showed that the voltage distribution in the windings can be made sufficiently uniform to be safe by shunting portions of the windings by employing small capacities. These capacities may be either external to the machine or built in it. Where shunt capacities are used, a lightning arrester should be applied to the terminals of the machine to limit the magnitude of the lightning voltages applied to the windings.

There are theoretical possibilities in the design of stator windings with shielding so introduced that the voltage will be distributed uniformly. Whether or not these are economically practical remains to be seen.

IV. Lightning Arresters in Shunt with Portions of the Winding

In a manner similar to that described in Section III, the distribution may be made uniform by shunting portions of the winding with lightning arresters whose voltage rating corresponds to the working voltage which will exist across their terminals.

In the above discussions, it has been assumed that the

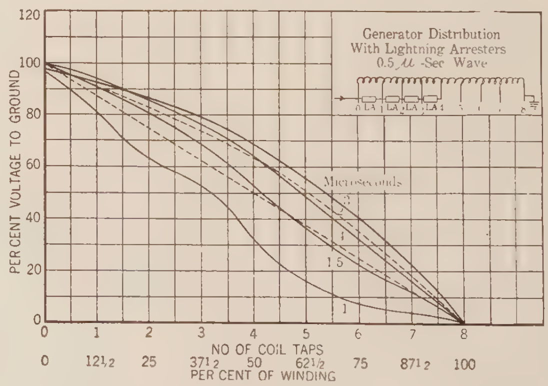

Fig. 12—Replot of Oscillograms, Winding Equipped with Internal Lightning Arresters, with ½-Microsecond Wave

neutral of the machine is grounded either solidly or through a relatively low resistance. However, when the neutral is free or grounded through a high resistance, the above data on distribution will in general still hold. In the latter case, it is to be recommended that a lightning arrester be applied from the neutral to ground; otherwise, because of reflections from the neutral point, high voltages may appear to ground or across portions of the winding.

In the application of any of the foregoing protective

methods except that of connecting the machine to the overhead line through the medium of an insulating transformer, each case should receive special consideration, as the characteristics of the protective equipment must be fitted to the characteristics of the machine.

The complete form of the paper contains an Appendix which gives a general discussion of the fundamental behavior of transients approaching a machine, and the effect on them of some of the protective schemes described.

The Pennsylvania Railroad Electrification

BY J. V. B. DUER[1]

Fellow, A. I. E. E.

Synopsis.—*This paper covers the electrification program of the Pennsylvania Railroad as recently announced and consists of a brief explanation of the reasons for the decision to embark on this electrification program, a review of the operating experiences leading up to the present designs used on the railroad, of catenary and transmission circuits, substation layout and types of equipment, as well as a description of the progressive steps of electric locomotive design which preceded the development of the electric locomotives to be used in this program, and concludes with a brief resumé of the points that should be given attention in applying an electrification to a stretch of railroad.*

* * * * *

ON October 31, 1928, General W. W. Atterbury, President of the Pennsylvania Railroad, announced that the Board of Directors had authorized a program of electrification, over a period of years, of the entire road train service, freight and passenger, between New York and Wilmington, Delaware, as well as the electrification of the grades between the Susquehanna, Schuylkill, and Delaware River Valleys, and the Eastern Terminal of the Railroad; a project covering a passenger and freight service of 325 mi. of line and 1300 mi. of track and extending from Hell Gate Bridge in New York, where connection is made with New England, west and south to Wilmington and west on the main line in the direction of Harrisburg.

The authorization of the Board of Directors to inaugurate this electrification work followed exhaustive studies of the whole industrial and transportation situations in the eastern part of the country, including the terminal developments already under way or projected for Philadelphia and Newark. While this analysis was worked out in detail, on the basis of the traffic estimated for the year 1935, the probability was not lost sight of that by 1950, the metropolitan area around New York would extend to New Brunswick on the west and well out on Long Island on the east and contain 30,000,000 people, and that there would be similar developments in other cities.

The system adopted is such that by the simple addition of increased power and increased rolling stock, a movement of any magnitude which it is possible to transport over the existing tracks and at a speed within the bounds necessary for safe operation may be handled as the demands of the traffic may from time to time require. The immediate factors which influenced the decision to proceed with the electrification were as follows:

1. The greater economy of electric traction as compared with steam operation in dense traffic territory.
2. The growth of the southern passenger business.
3. The increasing density of both freight and passenger business on our eastern lines and the probability that in the future more rapid movement would be required.
4. The desirability of utilizing the advantages of electric traction in connection with the construction of the new passenger terminals at Philadelphia and Newark.
5. The desirability of building a locomotive that would meet the requirements from the standpoint of weight of train, speed, and reliability which it is believed will have to be met in this territory in the next twenty years.
6. The probability that the project could be completed with a less total expenditure, all matters considered, than if started at a later date.

Of this program, the electrification of the New York Division, from Philadelphia to Trenton, has been completed and electrical suburban service inaugurated; electrification of the Schuylkill Division from Philadelphia to Norristown has been completed and electrical suburban service inaugurated; and at the present time electrification work is progressing from Sunnyside Yard and Jersey City to Manhattan Transfer and New Brunswick as an initial step in the operation of trains by single-phase locomotives from New York to Philadelphia, and for the operation of our suburban service between Jersey City and New Brunswick with single-phase multiple unit trains.

The announcement of this electrification program is the sequel to an interesting story of operating experience, of trial of electrical equipment, and of design and experimental work which started in 1905 when the Long Island Railroad was electrified, and which extends down to the present time when our electrification program is well under way and which covers experi-

1. Elec. Engr., Pennsylvania Railroad Co., Philadelphia, Pa.

Presented at the Pacific Coast Convention of the A. I. E. E., Portland, Oregon, September 2-5, 1930. Printed complete herein.

ments with d-c. electric locomotives and a complete trial of the single-phase system.

During the course of these experiments, an especially equipped section of the Long Island Railroad was used to develop the possibilities of this system, which, while not used for initial operation in the New York tunnels, was adopted shortly thereafter for the electrification of the suburban lines around Broad Street, Philadelphia. It has now been selected as our standard system for use in the electrification program upon which this railroad has embarked.

To be prepared for an extensive electrification, it was necessary to develop single-phase passenger and freight electric locomotive designs, as well as multiple unit car designs, and accordingly, in 1917 a constant speed, split-phase electric locomotive, (railroad classification FF-1,) was designed, built and tried out in service. The experience with this locomotive led to the development of a commutator motor type locomomotive (railroad classification L-5) of somewhat less horsepower than the constant-speed locomotive above referred to and having the variable-speed characteristics which experience seemed to teach were more

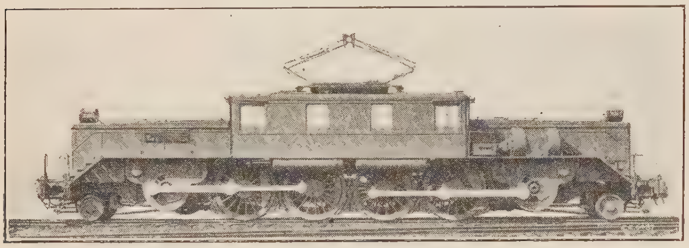

Fig. 1—Four Driving Axle General Utility Locomotive

Railroad Classification L-5

suitable for a railroad handling a dense passenger and freight traffic.

Locomotives of this design were built and placed in service on alternating current in the Philadelphia territory, and on direct current in the New York Terminal. They proved satisfactory and have given good service, and to the best of our knowledge, were the first electric locomotives built in this country in which a single design of mechanical chassis was used for the installation of the electrical equipment supplied by three different manufacturers, which parts, while not interchangeable with each other, produce a locomotive of practically identical transportation characteristics and of the same mechanical design.

In these locomotives, by change of gears, it is possible to have either a passenger locomotive for high speed or a freight locomotive for high tractive effort, and by change of type of control with which they are equipped, it is still further possible to utilize them on 600-volt d-c. circuits, or on 11,000-volt a-c. circuits. In other words, by minor modifications in construction, they were designed as a general utility locomotive for use either in passenger or freight service on alternating or direct current.

The study of electric locomotive design has been continuously directed toward the production of a simpler, more easily maintained, and more reliable locomotive, and shortly after the L-5 locomotive was built and placed in service, developments in the design of single-phase motors indicated to us that a still sim-

Fig. 2—Two Driving Axle Passenger Locomotive

Railroad Classification O-1

pler and sturdier locomotive could be produced, the progress in single-phase motor design having made possible motors of sufficient capacity to handle weights on drivers permitted on our railroad which could be placed between the driving wheels of the locomotive, thus eliminating the necessity for jack shafts and side rods.

It was thought desirable to design some locomotives having these general characteristics and, accordingly, the construction of ten passenger and two freight locomotives was authorized. These locomotives are of three types:

1. A two driving axle passenger locomotive having a

Fig. 3—Main Line Catenary and Transmission Line Construction

On the Philadelphia Terminal Division between Philadelphia and Paoli

four-wheel truck on either end (Railroad classification O-1).

2. A three driving axle passenger locomotive having a four-wheel truck on either end (Railroad classification P-5).

3. A four driving axle freight locomotive having a

two-wheel truck on either end (Railroad classification L-6).

The passenger locomotives have twin motors of 1060 hp. each, mounted above each driving axle and driving the wheels with gears and pinions through the medium of the well-known link type drive. The freight locomotive has axle mounted motors of 530 hp. each, driving the wheels through gears and pinions of the

Fig. 4—Main Line Catenary and Transmission Line Construction

On the New York Division between Trenton and Philadelphia

same general type of construction as in a street car.

The motors of all the locomotives are identical, the twin motors for the passenger engines being made up of two of the motors of the freight engines. All of the locomotives have roller bearings throughout—in the trucks, in the driving axle journals, and in the motor armature bearings,—the only plain bearings being those on axle to support the motors of the freight engine, and the quill bearings which support the quill in the frame of the twin motors on the passenger engines. The electrical apparatus on the locomotives is interchangeable to a very great extent, the auxiliaries and contactors are identical, and the transformers of the same design though of different capacities. These three types will be the standard until some further advance either in the art or in operating experience indicates further improvement in their design.

It might be interesting to note that locomotives of the L-5 and O-1 types were placed on the Locomotive Test Plant at Altoona and were given a thorough period of test to develop the complete operating characteristics before being put into the service. Two of the O-1 type have been completed and placed in service.

While the design and operating experience was going forward on the locomotives, the railroad was active also in developmental work in connection with the circuits for supplying the trains with current.

The initial installation in 1914 provided for 44,000-volt transmission circuits, indoor substations and oil circuit breaker equipment of relatively slow speed. A large part of the overhead catenary construction was of steel and was subject to frequent painting to keep it in condition for service. A brief summary of what has been done to make this layout of substations, transmission lines, and catenary construction, more adaptable to railroad operation, as well as to reduce maintenance costs, is as follows:

On more recent electrifications, 132,000-volt transmission is used instead of 44,000, thus providing capacity for the transmission of current from one end of a division to another and insuring against shut down due to the loss of any one source of energy.

Substations are now designed as outdoor stations, thus eliminating the major portion of the building with its attendant first cost and cost of maintenance.

Automatic circuit breakers are not used on the 132-kv. circuits, except at junction points where the circuits of one division must, under certain conditions, be automatically separated from those of another.

The trolley circuit breakers on our original installations operated in 12 cycles, including the relay action, and ruptured 30,000 amperes successfully. Our modern trolley breakers, however, must operate in one cycle, including the relay action, and rupture 50,000 amperes. One of the electric companies developed for our service an air break trolley circuit breaker not requiring the use

Fig. 5—Main Line 44-Kv. Substation at Bryn Mawr

Capacity four—2000 kv-a. transformers and necessary switching equipment

of oil and capable of rupturing currents of the same magnitude and in the same time as our latest oil trolley circuit breakers. We have purchased and installed many of these air breakers and they are giving successful service.

Experience with overhead catenary construction led us to believe that continuity of service secured by the

use of non-corrosive materials was of sufficient value in operating reliability to warrant the use of these materials and, accordingly, all of our catenary construction, except parts of material bulk, is of bronze or copper and such bulky pieces are galvanized malleable castings. By this means, painting and other maintenance attention to the overhead catenary system is reduced to a minimum and the continuity of use of track is raised to a maximum, this being of prime importance on a busy railroad.

There has been installed and is being tried out, a length of track with the overhead catenary riveted instead of bolted together as in the past. This construction gives every evidence of being successful and if this is the case, it will even further materially reduce the amount of attention which the overhead catenary system will require and still further increase the utility of the track beneath it.

A new type of rail bond similar to the well-known

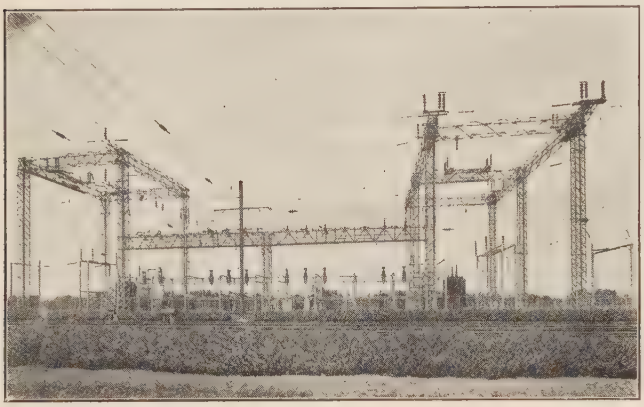

FIG. 6—MAIN LINE 132-KV. SUBSTATION AT EDGELY

Capacity 4—4500-kv-a. transformers and necessary switching equipment

signal bonds,—that is, a stranded cable welded or compressed at its ends into plug terminals driven into the rail by a hammer,—has been developed and is used on the Trenton and Norristown electrifications. The use of this bond reduces the initial cost of bonding materially and will, it is believed, reduce bonding maintenance to a minimum.

In conclusion, it may be interesting to indicate some of the questions involved in the actual application of electrification to a railroad after these various points have been considered.

First, an adequate and economical source of power supply must be provided either by providing for the purchase of current, or by designing and building a railroad power plant. This question may be settled largely on economic grounds, as railroad electrifications are now being operated successfully by power supplied from plants designed and built by the railroad companies and that purchased from electric companies.

Next, it is important to review the real estate situation along the section of railroad to be electrified, so that proper provision may be made for pole location, overhanging wires, and other questions of this character which may affect the placing of supporting structures and transmission circuits along the railroad right-of-way.

Substations are important and sometimes difficult to locate. They must not only be properly placed from the standpoint of voltage regulation, but must also be near a tower so that the apparatus in them may be readily controlled, and at a place where real estate is available or procurable.

A properly systematized working schedule should be prepared showing the beginning and completion of all designs and the dates for placing orders for material and for completion of the work. Items of work which should be completed before the electrification is started, such as the placing of communication circuits and signal power lines underground where this is necessary must be cared for. If this is not necessary, a careful check should be made to see that the poles on which these wires are supported do not interfere with the poles on which the electrification wires are supported and before electrification is started such changes must be made as are necessary to remove physical or electrical interference between them.

Provision of adequate overhead clearance of the trolley wire circuits must be carefully considered and changes made involving the lowering of tracks under highway bridges, or the raising of the bridges, as well as lowering of tracks in tunnels, or at other points where close clearances exist, in order to make room for the trolley wire.

Wires of other ownership crossing the railroad must be considered and the railroad wires erected at such elevations as to interfere to the least extent with these others, or changes made in such crossing wires as may be necessary to clear the railroad circuits.

The signals along the right-of-way must be carefully checked, that their location may coincide with the pole locations for the catenary construction and the changes in these locations confined to a minimum.

The character of signal circuits must also be checked and if necessary changed to properly coordinate them with the traction circuits.

After this preliminary work has been done, the pole foundations may be laid out, the poles designed and purchased, the substation sites prepared and the substation equipment purchased, arranging the dates of delivery of equipment and material in such a way as to meet as nearly as possible the actual erection schedule, thus holding unnecessary interest charges to a minimum.

In this connection, the great advantage of standardizing designs should be pointed out. As an example, if pole spacings can be kept standard, the

poles themselves may be standardized, the number of sizes and length of pole reduced to a minimum, the number of sets of catenary hangers also reduced to a minimum and the ease of production and erection materially assisted.

By standardizing pole spacings in terms of catenary hanger spacings, as well as by other means, it has been possible in our electrification work to reduce the number of types of poles used for a given section of track, say of 50 mi., from 150 different types of poles to 15 different types, and from several hundred different sets of catenary hanger lengths to two sets for tangent track and two sets for track of each radius of curvature used.

In addition to the actual application of the electrical circuits and substations to the railroad, the necessary multiple unit cars and locomotives must be purchased upon a schedule which will meet the completion dates of the electrification with as little overlap as possible and yet with sufficient overlap for safety, again reducing idle investment to a minimum.

This is a necessarily brief description of the electrification program of the Pennsylvania Railroad and the preparation which led up to it, but the work done will show results with the inauguration of the through electrification and will result it is believed in a service of maximum economy and reliability, with comfort to the traveling public.

Abridgment

A Survey of Room Noise in Telephone Locations

BY W. J. WILLIAMS[1] and RALPH G. McCURDY[2]
Member, A. I. E. E. Member, A. I. E. E.

***Synopsis.**—This paper describes a survey made to determine the range of magnitudes of room noise present in telephone locations. Measurements were made in a total of 250 locations in New York City and environs, distributed among businesses and residences in accordance with telephone traffic distribution. In each location, measurements were made by a marginal audibility method using the human ear as a part of the measuring device, and by a visual indicating meter. A brief description of the apparatus employed with each of these methods is included. Results presented for and measurements made in various classes of rooms, under winter and summer conditions.*

* * * * *

AMONG the projects of the Joint Subcommittee on Development and Research, of the N. E. L. A. and Bell System, is one which is studying the effects of noise[3] on telephone transmission and methods for its measurement. It was appreciated that in addition to noises of electrical origin, caused by exposures to power circuits or by sources incidental to the operation of the telephone system, there are also noises in the rooms in which telephones are used which have an important effect on telephone service. In studying the effects of noises, it is of course necessary to consider both noises of electrical origin and room noises. In fact, it was desired that in laboratory tests of the effects of line noises on speech transmission, typical amounts of room noise should be provided at the test location. The survey described herein was made to obtain room noise data for these laboratory tests.

The methods described should be of general interest in connection with other noise problems. Increasing attention is being given, both in America and in Europe, to the general problem of noise as an undesirable attribute of modern civilization. Effort is being made to investigate sources of city noise; modifications are being introduced in the design of machines and appliances, (typewriters, motor cars, electric refrigerators, rotating electrical machinery, and domestic oil burners) reducing the noise involved in their operation. Attention is also being given to quieting rooms by means of acoustic treatment, and study made of the effects of noise on living beings, including effects on the efficiency of workers.[4] In all of this work, quantitative measurement is important.

For the specific problem in hand, it was desired to obtain information on the magnitudes of room noises, as well as some general indication of the frequency composition of typical room noises.

While it is recognized that ordinary room noise is a

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3. In this joint work, noise is taken to mean any extraneous sound which would tend to interfere with telephone conversation.

Room noise is used to include any extraneous sounds at the place where the measurement is made, except those proceeding from the telephone receiver. It thus includes, in addition to noises such as the rattling of papers or the roar of street traffic, any other sounds extraneous to the telephone conversation, for example, those of other conversations or of music produced nearby.

Presented at the Summer Convention of the A. I. E. E., Toronto, Ont., Canada, June 23-27, 1930. Complete copy upon request.

4. D. A. Laird, "The Effects of Noise," *Journal of Acoustical Society of America*, January, 1930, p. 256.

highly variable quantity, changing from instant to instant in intensity and frequency composition, it was felt that sufficient measurements were made to specify the make-up of a typical room noise for use in the laboratory tests, and in addition to obtain an indication of the effect of various factors, described below, upon the noise. Since it was desired to make the measurements as representative as possible of typical telephoning conditions, they were made at times of day and in types of locations determined by a study of telephone message traffic. Since the results would be affected by the choice of locations, they are presumably less typical for non-telephone than for telephone purposes.

The residences included in the survey ranged from apartments in large city buildings to small homes in outlying towns. In the business locations were included offices, stores, factories, workshops, and public buildings, such as hotels and clubs.[5] Establishments of varying characteristics were included in each classification; they ranged in size from small stores to great manufacturing plants.

The survey consisted of two series of tests, one made during the months of January, February, March, and April, and the other made during the months of July and August. The former series was the more comprehensive, including 205 measurements; except where specifically noted otherwise the results given herein are based on this series of tests. The second series of tests was made for the purpose of determining the difference between the room noise encountered under winter conditions and that encountered under summer conditions. Consequently, a selected group of the locations which had been measured in the winter was measured again under summer conditions.

In generalizing from the data given, it must be appreciated that tests were made in only a limited number of locations.

Two methods were employed in making the measurements described in this paper—the electrical and the aural. The electrical method employed a condenser-transmitter pick-up, amplifiers and detector. A weight ing network was incorporated in the amplifier to simulate the sensitivity characteristic of the ear. The aural method, known as the "masking method," involved the measurement of the masking effect of the noise on various warbler tones recorded on a phonograph record. Both of these methods will be described in greater detail below.

General Results

Some of the interesting results which were obtained from this survey may be summarized as follows:

On the average, room noise in residences was about 20 db. less in magnitude than that in business locations.

5. In public buildings, only a very small proportion of the telephone locations tested were in booths or at coin-box telephones.

The spread in the magnitudes of business room noises was about 40 db., as compared to 20 db. for residence room noises. These spreads include 90 per cent of the measurements, excluding the lowest and highest 5 per cent. The standard deviation of the measurements was about 12 db. for business noise and 6 db. for residence noise.

Room noises averaged 4 or 5 db. higher in summer than in winter.

In general, the magnitude of residence noise was affected to only a minor extent by the size of the town or city in which it was measured.

On the average, the frequency composition of residence noise was about the same as that of business noise. The masking effect of the noise on a tone covering the range 750-1500 cycles, was greater than that on ranges above and below this. The magnitudes of components in the lower part of the range covered (about 250-5000 cycles) appeared to be somewhat larger than those in the higher part of this range.

Methods of Measurement

The two methods which were employed in the survey are as follows:

Aural Method—Masking of Warbler Tone.[6] In this method, a tone of varying pitch (warble) is produced and sent into a receiver. The receiver cap is provided with slots shaped so that the observer's ear canal is always open to the air of the room regardless of how firmly the receiver is pressed against the ear. The tone is generated by means of a phonograph record and a magnetic phonograph record pick-up, it is a variable-frequency tone, the pitch of which varies between certain limits several times per second. An attenuator is placed between the magnetic pick-up and the receiver. The observer sets the attenuator at a point where he can barely recognize the sound of the warble in the presence of the room noise; he also obtains the setting at which he can barely hear the warble in a perfectly quiet room. The difference between these two settings is a measure of the masking effect of the noise in this room upon the warbler tone, for this particular observer.

The phonograph records used in the present room noise survey were three-band records, *i. e.*, three warbler tones were cut on each record, each tone occupying about one-third of the available space. The frequencies included in the various bands were as follows: high band, 1500-5600 cycles per sec.; middle band, 750-1500 cycles per sec.; low band, 250-750 cycles per sec. In each band the frequency varied continuously from the lower to the upper limit and back to the lower limit, the period of such a complete "warble" being about one-sixth of a second.

Electrical Method—Room Noise Meter. There is of course a number of different electrical methods which

6. R. H. Galt, *Jl. Acoustical Soc. Amer.*, October 1929, p. 147.

might be employed for measuring room noise, ranging from a single over-all measurement to a complete wave shape or frequency analysis. The complete analysis, or the measurement of energy present in a considerable number of narrow frequency bands, is for such a survey as this, subject to the disadvantages of slowness of measurement and bulkiness of testing equipment.

The method adopted was one based on the use of a frequency weighting, approximately simulating the sensitivity of the ear. This frequency characteristic is

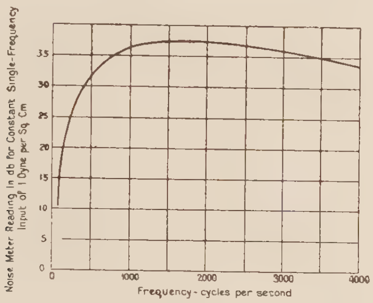

Fig. 1—Response Characteristic of Room Noise Meter

shown on Fig. 1. An electrical network furnishing this characteristic was built into a room-noise meter consisting of a condenser transmitter for converting acoustical energy into electrical energy, six stages of amplification for raising the level of the noise currents sufficiently to operate a thermocouple meter indicating device, and an adjustable attenuator between stages of the amplifier so that the noise energy being measured might be brought within the range of the meter over a range of levels of 80 db. (corresponding to a power range of 100,000,000 to 1). The sensitivity of the meter is such that a 1000-cycle tone with a pressure of about 0.014 dyne/cm.[2] would give a reading of 0 db. on the meter scale. This tone would be about 28 db. above the threshold of audibility for the average ear.

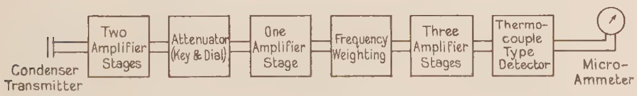

Fig. 2—Schematic Diagram of Room Noise Meter

Comparison of the Two Methods. In general, the meter method gives results in physical terms, while the masking method gives them in terms of effects on the ear; consequently, the choice of the method to be employed in any particular case depends somewhat on the use to which data will be put. It is true that the meter includes a network to simulate the sensitivity of the ear for various frequencies; it does not, however, simulate other properties of the ear, such as the departures from linearity in response by which subjective tones are produced by the ear mechanism, and the complicated way in which one sound masks another.,

The meter method, unlike the masking method. avoids any errors due to variations in human ears[7] This advantage is offset to some extent by the fluctuations of the meter needle, which makes it difficult to obtain the mean reading if the noise is unsteady, as is the case with most room noises.

In the case of noises of a distinctly intermittent, staccato character, the warbler tone can be heard and recognized in the brief intervals when the noise is a minimum. A preliminary investigation showed that for a noise of this sort, the relation between readings obtained by the masking method and by the meter method was different from the relation obtained for a steady noise, the warbler readings being relatively lower in the case of intermittent noise.

Both methods were used in the survey because it was felt that each gave information which could not be as accurately obtained from the other; and also because the use of two methods enabled each one to be used as a check upon apparatus defects which might occur in the other.

In using the masking method, data were taken by

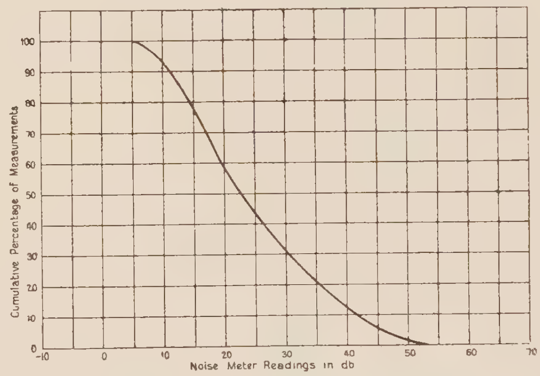

Fig. 4—Results of Noise Meter Measurements of Noise in Business Locations

two experienced observers and corresponding measurements averaged. All meter measurements were made by one observer.

Results of Survey

Noise in Business Locations. One hundred and nine business locations were visited. The magnitudes of the noises measured varied from that found in a doctor's quiet office to the din of a large manufacturing plant. Distribution curves for the noises measured are shown in Fig. 4 for the meter method and Fig. 5 for the masking method. For any point on one of these curves, the corresponding per cent of all of the measurements made had values equal to, or greater than, the indicated abscissa value.

It may be seen that with the exception of the high

7. R. L. Wegel and C. E. Lane, "Auditory Masking and Dynamics of the Inner Ear," *Physical Review*, February 1924.

curve of Fig. 5, the curves for meter and masking methods are fairly similar in shape. The middle curve has been selected to represent the masking method.

If there are excluded as extremes those noises which were so low that 95 per cent of all the noises measured equaled or exceeded them, and those which were so high that only 5 per cent of the measurements equaled or exceeded them, the spread of noise magnitudes is seen to be about 40 db. The standard deviation of the measurements is about 12 db.

As also shown on Figs. 4 and 5, the median business room noise would produce a reading of 23 db. on the meter scale and a masking of 26 db. on the high-frequency warbler tone, 39 db. on the middle-frequency tone, and 31 db. on the low-frequency tone. The average business room noise was about 2 db. higher than the median.

Some conception of the amounts of noise represented by these figures may perhaps be gained from the following. The extremely loud noise measured in a local

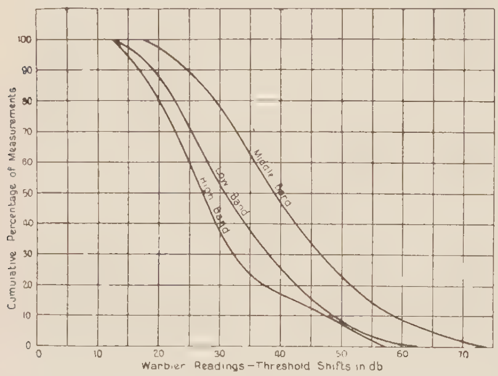

Fig. 5—Results of Measurements of Noise in Business Locations by Masking Method

station of the New York subway while an express train was passing produced a meter reading of 70 db. while the lowest noises measured in the survey, in quiet residences, gave readings nearly 0 db.

Data on noise at the business locations tested have been grouped so as to show the average differences in the room noise values obtained for different types of business and for different sizes of towns. It will be appreciated that only a very small number of measurements was included in each sub-classification, and that consequently it is not safe to generalize from these subgroupings as to room noise conditions in general. It was found, however, that the noise in the factory locations visited was substantially higher than that in other business locations, the factory average being about 15 db. above the general business average. In the case of factory locations, the majority of the measurements was made at telephones in rooms where manufacturing operations were being carried on. A substantial minority, however, was made in offices adjacent to such roots and affected by the noise from them.

The noise close to the machinery generally seemed substantially greater than that measured at the telephone.

It was also found that there was a general tendency for noise in business locations in the larger cities to be greater than that in small towns.

Room Noise in Residence Locations. Measurements

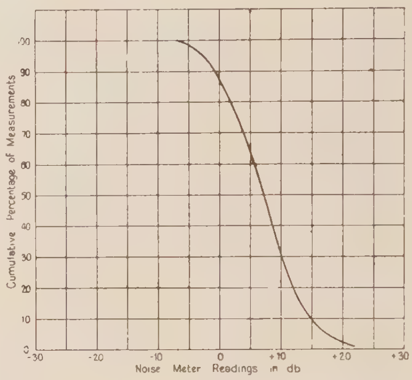

Fig. 6—Results of Noise Meter Measurements of Noise in Residence Locations

were made in 96 residence locations; Figs. 6 and 7 show distribution curves for these measurements. Compared with the corresponding measurements made in business locations, it is apparent that the room noises encountered in residences were not only much smaller in magnitude, but also varied less in magnitude than business room noises. The average of the residence room noises is about 18 db. less than the average of the

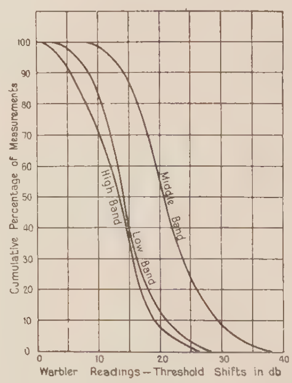

Fig. 7—Results of Measurements of Noise in Residence Locations by Masking Methods

business room noises, while the spread in residence room noise (using the 95 per cent and 5 per cent points on the curves as limits) is 20 db. compared with 40 db. for business noise; the standard deviation of the residence measurements is 6 db., compared with 12 db. for the

business measurements. Unlike the curves for business noise, the curves for residence noise are very symmetrical, showing similar distributions above and below the average values.

Figs. 6 and 7 also show that the median residence room noise would produce a reading of 7 db. on the meter, and a masking of 12 db. on the high-frequency warbler tone, 20 db. on the middle-frequency tone, and 13 db. on the low-frequency tone. The average was about the same as the median.

The average of the room noises measured in single-family houses was practically the same as the average of the noises measured in apartments.

The average of the residence noises measured in large cities was found to be practically the same as the average for smaller cities or for small suburban towns. This contrasts with the trend for business noise. The residences visited in large cities (Manhattan, Brooklyn, Newark) were largely apartments on side streets.

Comparison of Room Noise in Winter and Summer. Forty locations were visited both in summer and in winter and the data compared. It was found that both business and residence noises were somewhat greater in summer than in winter, the average difference being 4 or 5 db. The spread in values obtained under summer conditions was less than that found for the winter conditions. This was because the noises which showed the least magnitude when measured in winter were found to be higher under summer conditions, while the highest noises measured failed to show an appreciable change with season. These highest noises were largely caused by indoor machinery, and would not be appreciably modified by outside sources.

The average frequency composition of the noises measured under both summer and winter conditions seemed to remain about the same so far as could be determined.

Selection of Typical Room Noise and Its Reproduction. The data obtained have been used in determining the characteristics of a typical room noise to be recorded on a phonograph record and reproduced for use in laboratory tests.

Since the data revealed no difference between the average frequency composition of great and small noises, it has been possible to choose a single recorded noise and to vary merely the amplitude of the reproduced noise, keeping its frequency make-up constant.

The recording and reproduction of such a noise have presented problems, particularly from the point of view of naturalness. It has been found difficult to reproduce a noise by simple means in such a way as to give the illusion that the noise is real, not artificial. The requirements for reproducing a noise which will be typical in its effect on the intelligibility of speech transmitted over telephone circuit are considerably less severe however than those for obtaining naturalness. Three main factors seem to be involved in the problem: In the first place, room noises often contain high-frequency components, undoubtedly including some extremely high frequencies. These components, while they are generally of low energy content, seem to contribute substantially to the naturalness of the sounds. The effect of these components on the intelligibility of speech transmitted over a telephone circuit, however, would be much less than their contribution to the naturalness of the noise, since the transmitted speech is generally limited to a band of not more than 3000 cycles. The frequency band transmitted by the recording and reproducing system was nearly twice this amount, being limited both by the mechanical characteristics of the apparatus and by the unavoidable noise generated in this apparatus, the amount of this noise increasing as the band width increases. Secondly, room noises emanate from a considerable number of sources located in different positions, so that in order to reproduce them with complete fidelity, each source must be reproduced separately in its own position. On account of binaural effects in hearing, the proper locating of sources seems to have a considerable effect on naturalness. The most practical method of securing an approximation to this effect in the reproduced noise is to dispose a number of loudspeakers in different places in the room, chosen by test so that false directional effects are avoided. Thirdly, the effects of reverberation must be considered. A noise picked up in a highly reverberant room and reproduced in another highly reverberant room would have in it two sets of reverberations. The best method of taking care of this seems to be to make artificial adjustments in the reverberation in the two rooms. Finally, there is a residual effect due to the fact that a person experiencing an actual noise is aided in his recognition of that noise by visual and other factors, enabling him to refer it easily to its source; these are not present, of course, when the sound is reproduced.

Conclusions and Acknowledgment

While a certain amount of work on room noise conditions in telephone locations had been previously carried out, this survey represents a considerable advance in knowledge of room noise magnitudes. It provides data for work on the effects of noise on telephone transmission as well as furnishing certain information of wider interest. When further developed in the light of the experience gained in this work, the methods of measurement employed should prove valuable in other room noise investigations.

The authors wish to acknowledge the work of Messrs. J. W. Whittington and R. E. Philipson of the National Electric Light Association, and Messrs. J. M. Barstow and R. S. Tucker of the American Telephone and Telegraph Company, in designing and building the room-noise meter and in carrying out the survey.

Abridgment of

Development of the Porcelain Insulator

BY K. A. HAWLEY*

Member, A. I. E. E.

Synopsis.—Porcelain insulators have been manufactured and used for the transmission of high-voltage electric power for forty years. The first designs were of the single piece and multipart cemented pin type. Necessity of higher safety factors against flashover and increase in operating voltages demanded a rapid increase in the size of the insulators. This reached an economic limit at the operating voltage of 66 kv. The suspension unit overcame this temporary check of increased operating voltage.

Further study of the electrostatic capacitance of the various parts and consequent voltage distribution, made marked refinements in the pin type insulator possible. During this time the single piece porcelain suspension unit took practically its present form.

Early improvements were the provision of proper expansion joints and the separation of the lip of the cap from the porcelain hood.

Gradual improvements have since been made resulting in a great increase in mechanical strength. These changes have been principally of hardware design. By experiment and analysis the shapes of the cap and pin have been determined to give a uniform distribution of load from the pin to the cap. Constant check tests by the quick pull and time loading methods have shown, that the suspension insulator with properly designed hardware and a suitable coating on the cap to prevent the cement from adhering to the metal, to have a high strength associated with electrical reliability.

Ceramic research and exact manufacturing control has made possible the production of non-absorbent, thoroughly vitrified porcelain of consistent strength. This has centered largely about the proper firing of the clay.

Recent experiments upon the properties of the combination of porcelain and glaze has eliminated surface stress and consequently assured stronger, longer lived porcelain. Still greater uniformity has been gained by glazing the sanded surfaces.

The elimination of the abutting joint and the proper design of the cemented joint has stopped expansion troubles. Proper use of Portland cement has resulted in insulators able to withstand drastic temperature changes without harm. A recent improvement in the pin type insulator is the metal threaded pin hole. This has lessened manufacturing and construction difficulties and in addition due to the exact fit of the insulator on the pin, overcomes hidden corona and the consequent radio interference.

* * * * *

PORCELAIN insulators for the transmission of high tension electric power have been made and used for a period of approximately forty years.

The last decade of the nineteenth century marked practically the beginning of electric transmission in America and also the beginning of the continuous manufacture of porcelain insulators. Insulators of this decade were all of the pin type, both single piece and multipart cemented types. Many of these old insulators are still in use, although rarely at the operating voltages for which they were originally designed.

During the first ten years of the twentieth century pin type insulators advanced rapidly in size. Even at this early date it has reached its maximum economical size. For 66,000-volt transmission, pin type insulator proved to be quite satisfactory, but since the cost of the insulator varies as a power of its rating larger insulators of this type were not practical from a cost standpoint. The suspension insulator was the logical outcome of this temporary check. Plotting separate cost curves for equal arc-over values show that the curves cross at approximately the 66,000-volt operating range. This corresponds very closely to the usual practise and for the higher voltages the suspension insulator has almost invariably been used.

During the next decade from 1910 to 1920, marked refinements in the pin type insulator were made. The earlier insulators were little more than porcelain cups cemented together with but a slight understanding of voltage division.[1] The division of voltage is inversely proportional to the electrostatic capacities of the respective parts. These in turn are proportional to the adjacent conducting surfaces upon the porcelain, the cement being a conductor. As these surfaces were generally small on the central and top shells, these two parts carried most of the voltage. By careful study this condition was rectified and the correct balancing of the pin type insulator was one of the decided advances of this period.

During this decade the suspension insulator took practically its present form. The unit using two pieces of porcelain, while in many ways satisfactory, necessitated a larger head diameter and a correspondingly large size of metal cap. The single porcelain unit removed these unsatisfactory features and was accordingly almost universally adopted.

Experience promptly pointed out necessary refinements. Proper expansion joints were provided and the cap which originally had been allowed to rest on the porcelain was lifted, so that under all conditions it stayed clear of the hood. (Fig. 1.) With these improvements practically all field failures stopped. Insulators even of the largest size have established a perfect life record over a period of 15 years.

During the ten years just completed, there has been a decided improvement in the suspension insulator, not the result of any radical changes but rather a matter of refinements of design and manufacture. Slight changes in hardware shape, for example, have resulted

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Presented at the Pacific Coast Convention of the A. I. E. E., Portland, Oregon, Sept. 2-5, 1930. Complete copy upon request.

1. A. O. Austin, *Insulator Depreciation and Effect on Operation*, A. I. E. E. TRANS., 1914, p. 1731.

in more uniform distribution of load delivered to shell with a consequent greater uniformity and higher average mechanical strength. The desirability of such improvements is constantly evident. Unexpected loads greatly in excess of maximum calculated loads have been encountered and the strength of the insulator has been exceeded.[2] Three such failures upon insulators

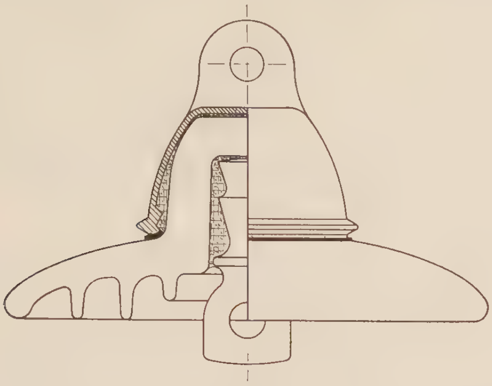

Fig. 1—Early 10-Inch Suspension Unit with Expansion Joint at Edge of Cap

of the old type have occurred in the past two years in widely separated localities.

It was at one time thought that the strength of the insulator was limited by the strength of the standard cement used, breakage resulting in loading tests from crushing and shearing of the cement and resulting in unfavorable loads on the porcelain. This is not so; a standard pin when cemented into a metal ring held consistently loads as high as twice the breaking strength of the insulator.

An analysis based upon directions of stress from cap

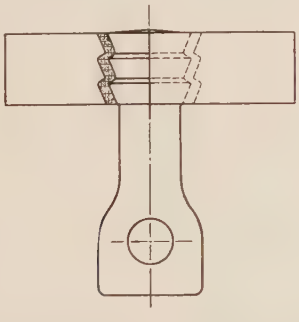

Fig. 2—Eye Bolt Cemented Into Steel Ring for a Tension Test of Cement Strength

to pin indicated possibilities of improvement in the design of the cap. Changes were made by filling the cap with babbitt and turning to the desired shape and as high as 50 per cent increase in combined electrical and mechanical strength resulted.

These caps when copied in malleable iron, however, showed no such improvement in performance. A close scrutiny of the previous tests on the caps containing the babbitt showed that under strain a slight slipping took place between the cap and the cement. Evidently the malleable iron caps must also be made to yield upon the cement. This research led to the painting of the inside surfaces of the cap with a suitable coating to prevent the cement from adhering to the metal. When this was done the desired results were obtained.

It was soon recognized that strength in quick pull-off was not always an indication of reliability. High strength against pulling apart must be associated with electrical reliability. The comparison of various available standard rated insulators brought interesting results. The insulator that had been heralded as the strongest showed on time test the earlist electrical failure. Table I shows this in detail.

The last two columns in Table I show the results of the previous research. The provision of a yielding abutment to the arch of the insulator with no changes otherwise had greatly strengthened the unit. By no known test could any hazard be shown.

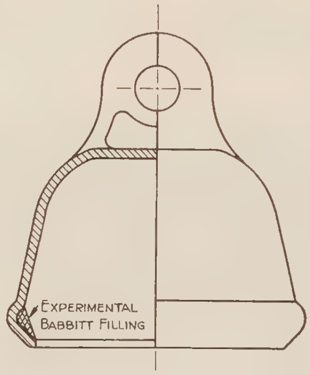

Fig. 3—Cap with Bearing Surface Filled with Babbitt to Desired Angle

In addition to this, periodical check tests are regular routine.

Efforts have been made to distribute the load upon the outside of the porcelain more uniformly by multiple stepped caps. No advantage in any test was observed and in many cases decidedly unsatisfactory results were forthcoming. The thin metal of the cap apparently yielded so that the upper step would carry more than its share of the load. Annular ridges within the caps are of the same character and are generally worse than useless.

Similar tests upon the pin, however, have always shown advantages from the multiple stepped pin, provided such steps are above the lower edge of the insulator cap. In this case, of course, the mass of the pin is sufficient to prevent any yielding.

Most of the early porcelains were thoroughly vitrified, but only too often with an excess of flux (feldspar). The comparatively thin sections allowed quick firing and rapid cooling. Such over-fluxing and rapid cooling can only result in ware that is lacking in strength, and there is little doubt that differences in performance of individual specimens of the same type and lot of the

2. M. T. Crawford, *Transmission Line Construction in Crossing Mountain Ranges*, A. I. E. E. Trans., 1923, p. 970.

TABLE I—TIME LOADING TESTS UPON STANDARD SUSPENSION INSULATORS

Load lb.	Insulator A		Insulator B		Insulator C		Insulator D		Insulator D revised	
	Hours held	Result	Hours held	Result	Hours held	Result	Hours held	Result	Hours held	Result
	String of 6		String of 6		String of 6		String of 12		String of 6	
6,000	150	O. K.	216	O. K.	96 72	2 *E* 3 *E*	168	O. K.	192	O. K.
7,000	168	O. K.	15	*M*	144 24	3 *E* 4 *E*	15	*M*	168	O. K.
8,000	48	*M*			96	4 *E*			168	O. K.
9,000					240	4 *E*			168	O. K.
10,000					168	5 *E*			24	*M*
11,000					168	5 *E*			24	*M*

E—Electrical failure. Numeral indicates total number failed.
M—Complete mechanical failure of one unit in string.

old insulators, were largely the result of variation in strength.

Over firing to the beginning of volatilizing of some of the ingredients (ceramically known as "bloat") has rarely been the cause of trouble. In fact, experience with such ware suggests that this condition may possibly be desirable rather than hazardous. The best

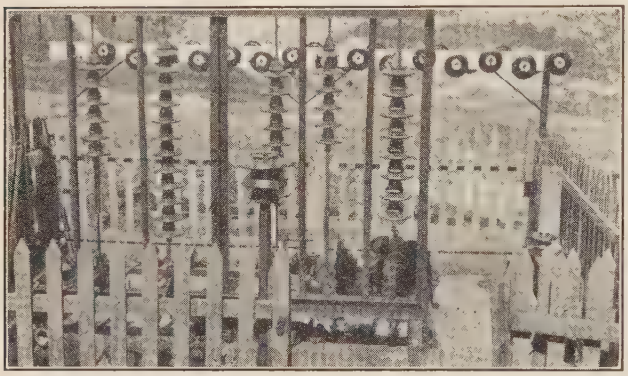

Fig. 4—Outdoor Frame at Victor

Outdoor loading frame for suspensions, levers and weights, used. Standard strength units carrying 5000 lb. and intermediate carrying 12,000 lb. since September 1927. All still sound.

porcelain today is recognized to be one of greater sturdiness, less flux, thorough vitrification, and careful cooling. Lesser flux means greater mechanical and electrical strength, but with this reduction in flux in the thicker sections, far greater care must be exercised in firing. Improper firing will invariably result in internal stress in the porcelain which seriously affects both the strength and life of the ware. Today constant thermal cycle checks are employed (A. I. E. E. Standard 41-250; 350). Such tests are largely a measure of the care used in kiln cooling. Regular porosity checks are made to insure thorough vitrification and proper coordination between all details of firing.

Recently greater strides have been made in the combination of porcelain and glaze. If the glaze covering the porcelain does not "fit" due to its coefficient of expansion being different from the porcelain it will be under stress. When this stress is above the elastic limit of the glaze crazing or crackling of the surface will be apparent. In the majority of cases, however, there are no visible cracks and yet the strains are there. Add an external load either of a mechanical nature or due to thermal changes to those already inherent in the surface of the dielectric, and small cracks will develop which will form the basis for a progressive failure of the porcelain.

Making and breaking in the testing machine comparative rods with various glazes pointed the way to the elimination of surface stress and the consequent development of stronger, longer lived porcelain. As an even more recent development, further strengths and greater uniformity have been gained by glazing the sanded surfaces.[3]

The abutting joint in the insulator assembly wherever found has been a source of trouble. As already explained, the separation of the cap of the suspension insulator from the horizontal hood has stopped losses in that type. Similar breakages occurred when the

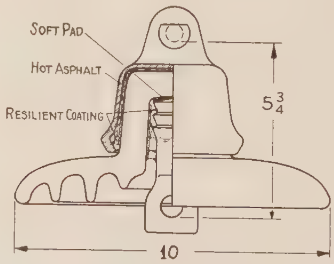

Fig. 5—Modern Cemented Suspension Insulator showing Provision for Expansion and Yielding Joints

caps of switch type insulators were placed upon the porcelain so that the cement would bear upon the fillet between the head and the horizontal hood. Wherever this has been done, especially in climates where freezing occurs, there have been insulator losses. When the cap and the cement within it have been kept above this fillet these breakages have not occurred.

When the cap shrinks with cold or when free water between the cement and porcelain freezes there is a radial pressure against the fillet with an upward component. This reaction becomes a tension stress upon

3. D. H. Rowland, *G. E. Review*, March 1929 and June 1930.

the porcelain—a stress which it is least able to carry.

If the cement is above the fillet the stress is entirely horizontal and becomes purely a compression force upon the porcelain. Against such stress porcelain is one of the strongest materials known.

Another form of the abutting joint is that which was used largely in pin type designs in the past. In this case the joint was between two porcelain parts. This,

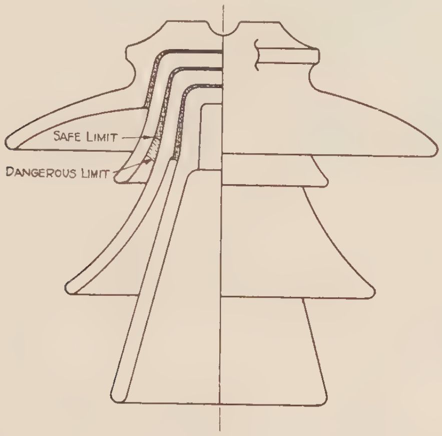

FIG. 6—SAFE AND DANGEROUS LIMITS IN CEMENTED JOINTS

commonly known as the closed joint, was used chiefly for two purposes. First, such an insulator would be free from corona display at relatively high voltages, and second, the self-alining features of the closed joint offered a decided advantage in ease of factory assembly. The cause of the breakages experienced with this type of insulator was the same as with the suspension of switch type already described. The outer piece, however, in this case was generally the weaker and was usually the first to break. The edges of the upper porcelain part at the joint were frequently thin and were consequently weakened by over-firing because of this thinness.

Portland cement has been blamed for many insulator failures. It is certain that the chief complaint is not against the cement but against its improper use.

Examination of the open type of cement joints shows that insulator failures have almost always occurred in those insulators with wide cement joints or with great cement masses, or with overfilled tapered joints.

All cement when drying shrinks. Mixtures which contain the smallest percentage of water are those which show the least shrinkage when drying. Such mixtures are also stronger. The use of 1/3 sand in the mix will cut down the shrinkage exactly 1/3 and make the material much more inert. When the cement shrinks against the parts within there is a tendency towards cracking of the cement. This cracking is reduced to a minimum, if not prevented entirely, if the cement joints are narrow, if the cement is dense and strong, and if it is firmly anchored in place by sanded surfaces upon both sides of it. Where insulators with these features have been found there have been no breakages.

On the other hand, where there has been an excessive cracking of this cement or where water can find a passageway between the cement and porcelain the freezing of that water and the consequent increase in volume is frequently accompanied by a failure of porcelain. Such breakages have been observed to occur immediately adjacent to a crack in the cement as a result of localized pressure.

An examination of insulators made over a long period of time shows that they can be separated into groups, one of which may be expected to fail and the other not. This dividing line has been sufficiently sharp and close that a reasonable insulator life may now be confidently predicted. The modern insulator is made with cement joints as narrow as manufacturing tolerances will allow, while the cement used is dense and contains a minimum amount of water in the mix. The joints are not overfilled and the cement is fully set and expanded by curing at a suitable temperature in a saturated atmosphere.

One of the recent improvements in the pin type insulators has been the metal threaded pin hole. It is relatively difficult to manufacture porcelains with the thick sections demanded by modern practise. These thick sections even under the best controlled conditions do not shrink uniformly. This results in a distortion of the pin hole which cannot be accurately foretold and compensated for. Realization of this led to the adoption of the metal thread. This thread is now quite uniformly used in the pin type insulators of the higher voltages. Not only does it simplify construction and save time due to the exactness of its fit upon the pin, but in addition it is of special value in

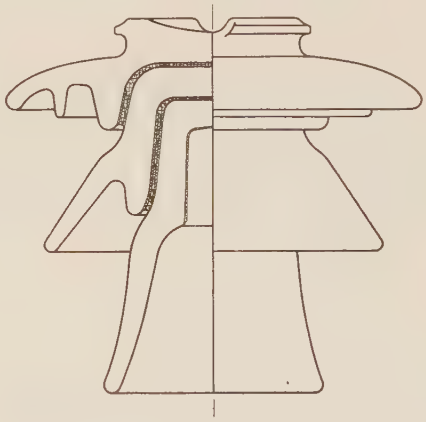

FIG. 7—PIN TYPE INSULATOR

Cement joints properly filled and proportioned

overcoming a hidden source of corona which might cause hidden stress and radio interference.

While we believe that the developments in insulator art have been worthy ones, we are by no means drifting into a self-satisfied condition. Organized research is constant and consistent and all indications are that insulators will not be the restraining factors in any future developments no matter how rapid those developments may come.

Institute and Related Activities

The Pacific Coast Convention

SEPTEMBER 2-5

A program with a variety of technical subject matter, excellent entertainment, adequate facilities for sports, and interesting inspection trips to hydroelectric power developments is offered to those who attend the Convention at the Multnomah Hotel, Portland, Ore., September 2-5.

Seventeen technical papers are scheduled for presentation in five technical sessions on the following subjects: Transmission, Power Stations, Communication, and Research and Development. In addition, two student sessions will be held and papers will be presented by the students. A program and list of technical papers which are to be presented was published in the August issue of the JOURNAL, page 689.

Louisville Meeting

NOVEMBER 19-22

A meeting of the Southeastern District, No. 4, will be held at Louisville, Kentucky, November 19-22. Active interest on the part of the local committee which is making the arrangements for the program indicates that there will be five technical sessions on the following subjects: Electrolysis, Transportation and Industrial Applications, Transmission and Distribution, Power Generation and Electrical Machinery, and possibly Protective Devices.

Interesting inspection trips to points of engineering, historical, and scenic interest will be arranged. The Ohio Falls Hydroelectric Plant, Waterside Steam Station, and the Dix Dam Hydroelectric plant may be inspected, and the Mammoth Cave, Lincoln Farm, Old Kentucky Home, and Bluegrass Section visited.

Middle Eastern District Meeting at Philadelphia October 13-15

A meeting of the Middle Eastern District, No. 2, will be held in Philadelphia, October 13-15 inclusive, with headquarters at the Benjamin Franklin Hotel. The local committee making the arrangements for the Meeting have adapted an excellent program of events comprising five technical sessions, a Student session, an informal reception with dancing, a meeting banquet, a number of interesting inspection trips, and facilities for sports at the various country clubs. Special trips of particular interest to the visiting ladies are arranged in the Ladies' Program.

Technical papers of unusual interest, some of which are associated with local engineering projects such as the Pennsylvania Railroad electrification, Reading Company's railroad electrification, substations of the Broad Street Subway, and using railroad rights-of-way for power transmission purposes, are to be presented in five technical sessions. A list of papers, together with the names and affiliations of their respective authors and the sessions in which they are to be presented, is published in a following part of this announcement.

A student session at which specially selected papers will be presented by the students will also be held on Monday afternoon.

Technical sessions have not been scheduled for Wednesday afternoon so that those who may wish to do so may attend the Dedicatory Exercises of The James Ward Packard Laboratory of Electrical and Mechanical Engineering at Lehigh University, Bethlehem, Pennsylvania.

OUTLINE OF PROGRAM

MONDAY, OCTOBER 13TH

MORNING Registration
Opening of meeting
Technical session on Radio and Communication
AFTERNOON Technical session on Hydroelectric Power
Student session
EVENING Informal reception—dancing

TUESDAY, OCTOBER 14TH

MORNING Technical session on Electrical Equipment and selected subjects
AFTERNOON Technical session on Transmission
EVENING Meeting banquet

WEDNESDAY, OCTOBER 15TH

MORNING Technical session on Railway Electrification and Electric Traction
AFTERNOON Board of Directors meeting

Entertainment

Entertainment features of the Meeting will include an Informal Reception with dancing on Monday evening, and the Meeting Banquet on Tuesday evening, both to be held in the Crystal Ball Room of the Benjamin Franklin Hotel. A golf tournament has not been arranged but facilities of the many attractive country clubs of the Philadelphia District will be available for those desiring to play golf.

LADIES' PROGRAM

MONDAY, OCTOBER 13TH

MORNING Visit to Wanamaker's store
AFTERNOON Tea in the Betsy Ross room of the Benjamin Franklin Hotel
EVENING Informal reception and dancing at the Benjamin Franklin Hotel

TUESDAY, OCTOBER 14TH

MORNING Sightseeing trip—historical Philadelphia
AFTERNOON Luncheon and bridge at the Philadelphia Country Club
EVENING Meeting banquet at the Benjamin Franklin Hotel

WEDNESDAY, OCTOBER 15TH

MORNING Trip to New Art Musuem
AFTERNOON Trip to Valley Forge

Within a short distance of the Meeting headquarters are many places of historical interest, such as Independence Hall, Carpenters Hall, Betsy Ross House, Old Christ Church, and also the splendid home of the *Ladies' Home Journal* and *Saturday Evening Post.*

TECHNICAL PROGRAM

MONDAY, OCTOBER 13TH

MORNING Radio and Communication

E. B. TUTTLE, *Presiding*

Aeronautical Radio Communication, Eugene Sibley, Department of Commerce, Washington, D. C.

Telephone Trunking Plant in a Metropolitan Area, A. P. Godsho, Bell Telephone Company of Pennsylvania

Miscellaneous Noise Measurements, J. C. Steinberg, Bell System Laboratory

AFTERNOON Hydroelectric Power Generation (In parallel with student session)

LYLE A. WHITSIT, *Presiding*

Hydraulic and Electrical Possibilities of High-Speed Low-Head Developments, George A. Jessop, S. Morgan Smith Co., and C. A. Powel, Westinghouse Electric & Mfg. Co.

Trend in Design and Capacity of Large Hydroelectric Generators, M. C. Olson, General Electric Co.

Automatic Economy Control Applied to Hydraulic Plants, S. Logan Kerr, I. P. Morris Corp.

Damper Windings for Waterwheel Generators, C. F. Wagner, Westinghouse Electric & Mfg. Co.

TUESDAY, OCTOBER 14TH

MORNING Electrical Equipment and Selected Subjects

R. A. HENTZ, *Presiding*

Air Conditioning in Industry, A. H. Clogston, Cooling and Air Conditioning Corp.

Outdoor Switching Equipment at Northwest Station, W. F. Sims and C. G. Axell, Commonwealth Edison Co.

A New System of Speed Control for A-C. Motors as Applied to Power Station Auxiliaries, A. M. Rossman, Sargent and Lundy

Transformer Load Ratio Control, A. Palme, General Electric Co.

Forces in Turbine Generator Stator Windings, J. F. Calvert, Westinghouse Electric & Mfg. Co.

AFTERNOON Transmission

R. A. HENTZ, *Presiding*

Electrical Porcelain, H. M. Kraner, Westinghouse Electric & Mfg. Co.

75-Kv. Submarine Cable for Deepwater Station, R. W. Wilbraham, United Engineers and Constructors, Inc.

Magnitudes and Rates of Rise of Circuit Breaker Recovery Voltages, R. H. Park and W. F. Skeats, General Electric Co.

Lightning, Edw. Hansson, Pennsylvania Water and Power Co.

WEDNESDAY, OCTOBER 15TH

MORNING Railway Electrification and Electric Traction

G. I. WRIGHT, *Presiding*

Power Supply Facilities for Reading Suburban Electrification, C. L. Doub, Reading Co.

Substations of Broad Street Subway of Philadelphia, H. M. Van Gelder, City Transit Commission

The Internal Combustion Engine as an Adjunct to Electrification, A. H. Candee, Westinghouse Electric & Mfg. Co.

Utilization of Railroad Rights of Way for Electric Power Transmission and Coordination with Railroad Electrification, W. W. Woodruff, Philadelphia Electric Co., and G. I. Wright, Reading Co.

Initiating an Electrification into Operation, H. C. Griffith, Pennsylvania Railroad Co.

The Modern Single-Phase Motor for Railroad Electrification, F. H. Pritchard and F. Konn, General Electric Co.

Inspection Trips

As a large number of plants of interest to the electrical engineering profession is located in and near Philadelphia, a wide variety of trips will be available. Arrangements may be made with the local committee to visit these plants during the Meeting.

The great activity in railroad electrification has led the committee to arrange for an inspection trip to view the Pennsylvania Railroad electrification, utilizing 132,000-volt transmission, the comprehensive West Philadelphia Terminal improvements, and the Lamokin Substation of the Philadelphia Electric Company, in which are installed three 150,000-kw. 60- to 25-cycle frequency changers supplying the Pennsylvania electrification.

The General Electric Company's main switchboard and oil circuit breaker plant in West Philadelphia, the Westinghouse Electric and Manufacturing Company's turbine plant at Essington, Pa., and the American Brown Boveri Company's plant at Camden, N. J., are open for inspection. Many new and interesting features will be shown to delegates and guests.

Short trips may be made to inspect two recently constructed 600-volt d-c. railway substations equipped with 600-volt d-c. mercury arc rectifiers, one substation utilizing steel clad switchgear and the other substation of the full automatic type.

Arrangements may be made to inspect the 252,000-kw. Conowingo Hydroelectric Development on the Susquehanna River approximately 60 miles from Philadelphia, and the new Deepwater Steam Generating Station, approximately 30 miles from Philadelphia, the Deepwater station operating at 1200 lb. pressure with pulverized fuel firing. Each of these two trips will take the better part of a day.

For those who are interested in the latest developments in radio receiving set manufacture and communication inspection trips may be made to the Radio-Victor Plant in Camden, N. J., and to the Atwater Kent Plant in Philadelphia.

The Radcliffe Dial Switching Station of The Bell Telephone Company of Pennsylvania will be open for inspection to those delegates who are interested in the most recent developments in dial telephone switching.

Richmond Station, other generating stations, and substations of the Philadelphia Electric Company will also be open for inspection.

Arrangements may also be made to inspect the Plymouth Meeting Substation approximately 10 miles from Philadelphia, the focal point for the 220,000-volt lines connecting with the Conowingo Station and the systems of the Pennsylvania Power and Light Company and the Public Service Electric and Gas Company of N. J. At this substation are installed three 133,000-kv-a., 220,000 to 66,000-volt transformer banks for supply of energy to the 66-kv. system of the Philadelphia Electric Company. Recent installations of high-speed oil circuit breakers and high-capacity transmission line construction on private rights-of-way and on railroad rights-of-way can be seen on this trip.

Arrangements may also be made with the local committee for inspection trips to many other points of interest to the electrical engineer.

Hotel Accommodations

The Meeting headquarters will be at the Benjamin Franklin Hotel, rates for which are given below. Advance registration should be made direct with the hotel at as early a date as possible because a large convention of another organization will be held in Philadelphia during that same week.

RATES PER DAY—EUROPEAN PLAN

Single Rooms		Double Rooms		
With shower and bath	With bath	With shower bath and twin beds	With shower and bath	With bath
$5.00	$4.00	$8.00	$7.00	$6.00
6.00		9.00	8.00	
7.00		10.00	9.00	
8.00				

Committee

The District Meeting Committee which is making arrangements for the meeting, consists of the following: E. C. Stone, Vice-President, Middle Eastern District; J. A. Cadwallader, Secretary, Middle Eastern District; L. F. Deming, Vice-Chairman, Philadelphia Meeting Committee; A. J. Althouse, F. C. Caldwell, D. H. Kelly, W. B. Kouwenhoven, W. H. LaMond, and R. H. Silbert.

Nineteenth Annual Congress of the National Safety Council

Through C. E. Pettibone, President, and W. H. Cameron, Managing Director, the National Safety Council is extending a cordial invitation to all members of the Institute to attend its Nineteenth Annual Safety Congress, meeting at the William Penn and Fort Pitt hotels, Pittsburgh, Pa., September 29-October 3, inclusive, with special exhibits in the William Penn exhibit halls.

This is looked upon by the Council as one of its most important conferences of the year, relating as it does to accident prevention in public utilities industries. Special sessions will be under the auspices of the Steam and Electric Railroad Section, (organized 1915), the Marine Section (organized 1923—but reorganized in 1917 under the name of Marine and Navigation Section); the Aeronautical Section (organized 1928), and the Section which has now developed into the Taxicab and Bus Section, first organized in 1922. The Electric Railway Section will have three half-day sessions and an additional joint meeting with the Public Utilities, Street and Highway Traffic Section, and Delivery Taxicab and Bus Sections, one of the features being an address by Mr. Charles Gordon, Managing Director of the American Electric Railway Association on the subject of "Improved Public Relations as the Result of Safe Operation." The special exhibit will be supplemented by educational displays by the United States Navy and Bureau of Mines.

National Power Show

Under the leadership of I. E. Moultrop, Chairman, preliminary details of the Ninth National Exposition of Power and Mechanical Engineering to be held December 1st to 6th, in Grand Central Palace, New York City, are well underway. It has been stated by the committee in charge that the problem of finding space to fit in new exhibitors who are planning to come in, is already a real one; and the Grand Central Palace will be crowded.

Since the National Power Show will not be held in 1931 this forthcoming Exposition will draw better exhibits and a record attendance of visitors.

The character of the Advisory Committee indicates the interest and ramifications of the exhibits and their importance to the several engineering professions and industries. They are Homer Adams, Past-President of the American Society of Heating and Ventilating Engineers. N. A. Carle, Manager the Pacific Electric and Mfg. Co.,—H. D. Edwards, President American Society of Refrigerating Engineers,—Fred Felderman, Past National President National Association Stationary Engineers,—Vincent M. Frost, Chairman Power Division American Society of Mechanical Engineers,—L. A. Harding, President American Society of Heating and Ventilating Engineers,—C. F. Hirshfield, Chief Research Department, Detroit Edison Company,—O. P. Hood, Chief Mechanical Engineer, U. S. Bureau of Mines, —John H. Lawrence, President Thomas E. Murray Co.,—Fred R. Low, Past-President American Society of Mechanical Engineers,—David Moffett Myers, Consulting Engineer,—Fred W. Payne, Co-Manager Exposition,—Charles Piez, President American Society of Mechanical Engineers,—Joseph W. Roe, Chairman Professional Division American Society of Mechanical Engineers,—Charles F. Roth, Co-Manager Exposition, and the President of the National Electric Light Association.

STANDARDS

Four New Standards Now Available

The following new Standards pamphlets have become available within the last two months:

No. 12 Constant Current Transformers of the Moving Coil Type

No. 13 Transformers, Induction Regulators and Reactors (Revised edition)

No. 20 Air Circuit Breakers

No. 26 Automatic Stations (Revised addition)

Report on Standards for Capacitors

The proposed Standard for Capacitors, No. 18, developed by a subcommittee of the Electrical Machinery Committee is now available in pamphlet form for purposes of criticism and suggestions. These standards apply to capacitors for the following types of service: 1, Power applications—power factor correction, high-frequency induction furnaces, capacitor motors; 2, Resonant shunts (filters); 3, Blocking capacitors; 4, Coupling capacitors; 5, Power oscillator circuits. Copies of the pamphlets sent to those interested without charge. Address your communication to Secretary A. I. E. E. Standards Committee, 33 West 39th St., New York, N. Y.

Report on Standards for Railway Control Apparatus

This new Report on Standards for Railway Control Apparatus No. 16, is a suggested revision of the present Standard No. 16, entitled "Railway Control and Mine Locomotive Control Apparatus." Incidentally the present Standard No. 16 has been split into two parts, one dealing entirely with Railway Control Apparatus and the other to be developed by a Sectional Committee will cover Mine Locomotives and Control Apparatus. Copies of Report No. 16 can be obtained free of charge by those interested by addressing the Secretary A. I. E. E. Standards Committee, 33 West 39th St., New York, N. Y.

Report on Standards for Graphical Symbols Used for Electric Power and Wiring

A new revision of the former Report on Standards for Graphical Symbols Used for Electric Power and Wiring, No. 17g2, has just become available. The original Report No. 17g2, issued in March 1930 was circulated widely and many criticisms and suggestions were obtained. In view of these comments, the subcommittee preparing the report deemed it advisable to issue the revised report. Copies may be obtained free of charge by those interested by addressing the Secretary A. I. E. E. Standards Committee, 33 West 39th Street, New York, N. Y.

Recommendations on the Operation of Transformers

Recognizing the economic importance, and the demand on the part of users of large expensive apparatus, of obtaining in service outputs greater than the test rating as defined in the A. I. E. E. Standards, the Institute has issued this pamphlet. No. 100, Recommendations on the Operation of Transformers, It furnishes a guide on the operation of transformers in service, where operating conditions are different from those specified in the Standards for acceptance tests.

Also, recognizing the difference in maintaining the temperatures continuously at the maximum value by means of allowing overloads and of reaching the maximum temperature occasionally under usual service conditions where the test rating is never exceeded, the A. I. E. E. establishes for the first time a temperature differential of 10°C in the recommended maximum temperatures for the two kinds of service.

These recommendations on operation are published as an individual pamphlet in order to distinctly separate them from the material used as the basis for the purchase of transformers as contained in the present A. I. E. E. Standard No. 13. Copies of No. 100 may be obtained by sending your order accompanied by necessary remittance to Secretary A. I. E. E. Standards Committee, 33 West 39th St., New York, N. Y. The price is 20 cents with 50% discount to members of A. I. E. E.

Proposed Standard Tests of Broadcast Radio Receivers

In the August 1930 issue of the Proceedings of the Institute of Radio Engineers there was published a revision of the 1928 report on "Proposed Standard Tests of Broadcast Radio Re-

ceivers." All those interested are urged to get a copy of this proposed Standard and then transmit their comments or suggestions to the Committee on Standardization, I. R. E., 33 West 39th St., New York, N. Y.

Special Courses at Stevens

The curriculum of Stevens Institute of Technology for the academic year 1930-1931 will include for the first time in its sixty-year history, courses for graduate students. Heretofore it has offered a general, unspecialized course in engineering and has given only the undergraduate degree in course. Since the inauguration of President Harvey N. Davis, a Faculty Committee has been investigating the field of graduate instruction, and following the recommendation of this committee, the Trustees and Faculty have approved a program of graduate courses leading to the degree of Master of Science.

As a part of these graduate instructions, Doctor William A. Shewhart, of the Bell Telephone Technical Staff beginning September 23, will give a special course entitled "Statistical Theories and Methods Applicable to the Economic Control of Quality in Manufactured Products." Professor F. C. Stockwell, Chairman of the Faculty Committee on Graduate Instruction, by way of announcement states that "many engineers and others in the metropolitan area who are interested in the theory of statistics and its practical application will wish to register for this late afternoon course scheduled for Tuesdays and Thursdays from 4:00 to 5:30 p. m."

Diesel Engine Course Reflects Latest Developments

For the seventh year, the Brooklyn Polytechnic Institute of Brooklyn, N. Y. offers to the general public an evening course in the study of the Diesel engine. The course will start Tuesday evening, September 30 at 7:30 p. m. In view of the rapid developments, the course has been revised to keep it completely up to date with modern practise.

The Institute offers a course of twenty lectures to be given on Tuesday evenings; the lecturer being Mr. Julius Kuttner, Editor of Diesel Power. The subject of these lectures are as follows—1. Diesel Engine Principles. 2. Four cycle Diesel engine and its valve gear. 3. Airless injection and spray valves. 4. Two cycle Diesel Engine. 5. Air injection of fuel. 6. Fiel Pumps. 7. Air injection compressors. 8. Governing of Diesel Engines. 9. Diesel fuels and their combustion. 10. Reversal of Marine Diesel engines. 11. Cylinders. 12. Diesel lubrication. 13. Cylinder heads. 14. Diesel railway traction. 15. Piston ring action. 16. Large pistons and their cooling. 17. Trunk pistons. 18. Diesel engine framework. 19. Major bearings. 20. Aeronautic and high speed Diesel Engines.

In addition to these lectures a supplementary course consisting of informal classroom discussions and laboratory experiments is offered on alternate Monday evenings from 6:00 to 9:30 p. m., Professor F. D. Carbin of the Polytechnic Institute conducting these informal discussions of the lecture preceding. Here the student may ask questions and clear up doubtful points. Professor W. J. Moore of the Institute will conduct the laboratory periods with tests and demonstrations on Diesel and Oil engines.

The course is open to the general public, irrespective of their previous education. Complete information on the course may be had by addressing Professor F. D. Carvin, Polytechnic Institute, 99 Livingston Street, Brooklyn, N. Y.

I. E. S. Sponsors Courses in Fundamentals of Architecture for Illuminating Engineers

In order to be of real service to the architect, the Illuminating Engineering Society believes that the illuminating engineer must know more of the architect's problems and discuss matters with him in his own language. Two courses in the fundamentals of architecture for illuminating engineers are therefor being organized by the Society to be held concurrently in the early fall.

One of these courses, limited to 75 registrations, will be held at the Architectural League Club House, New York City, under the auspices of Columbia University, from September 8 to 13, inclusive, of which previous notice was given in the July issue of the Journal, p. 576, and the other limited to 100 registrations, to be held concurrently at the Art Institute, Chicago, by the Schools of Architecture of the University of Illinois and the Armour Institute. Both courses will consist of two lectures a day for five days in the fundamentals of architecture and allied subjects, by Professors of Architecture of the respective Universities. After lunch each day, the groups will be addressed by prominent architects and they will then be taken on inspection trips to interesting buildings. On the morning of the sixth day, a general open forum will be held to summarize the work.

The Augustus D. Curtis Award

For the purpose of giving recognition to the individual or individuals, in any member power company of the National Electric Electric Light Association that contributes most to the advancement of the electric lighting (interiors or exteriors) of commercial and public buildings, the Curtis Award is offered for the calendar year. It is retroactive so that the previous six months' activity may be included in any presentation for the full calendar year 1930.

The contest will include accomplishments realized up to December 31st, 1930 and each calendar year thereafter. Exhibits must be filed at National Electric Light Association headquarters on or before April 1st of the year following the period of the contest. Announcement of the winner will be made at the Annual National Electric Light Association Convention.

This contribution may be in the form of: (A) Stimulating new and better uses of lighting. (B) A method of lighting that is a distinct advance over present practise. (C) The development of a lighting service activity outstanding in its accomplishments. (D) The promotion of cooperative activities for the betterment of lighting. (E) Relighting the properties of the utility. (F) The elimination of barriers to good lighting.

The Curtis Award is a certificate to the company and five hundred dollars in gold to the person in the company that shows the greatest contribution to commercial electric lighting under the terms as above outlined. It is intended that presentation of the cash award will be made to the person submitting the written exhibit, and be distributed to the individual or individuals responsible for the achievement.

Registration blanks may be secured from the Commercial Department, National Electric Light Association, 420 Lexington Avenue, New York City.

A New Center for Science and Engineering to Open

By Prof. Albert B. Newman, Head of the Department of Chemical Engineering, it is announced that a new center of adult education in science and engineering will be opened this Fall at Cooper Union.

Engineers and other industrial scientists throughout the New York area recognize the need of organized study to prevent falling behind the developments in scientific investigation, Prof. Newman says. Members of the faculties of colleges and technical schools will also enroll in advanced evening lecture courses in chemical engineering and physics to be given at the Union during the coming academic year.

Professor Karl F. Herzfeld of Johns Hopkins University, a former professor of physics in the University of Munich, and who received his early training in Vienna and is the author of a treatise

in German on the kinetic theory of heat, will present a survey of the field of modern physics under the auspices of the Department of Chemical Engineering and the Department of Physics, of which Professor Albert Ball is the head.

The topics to be covered are closely related to chemical theory.

The National Hydraulic Laboratory

The National Hydraulic Laboratory Act was signed by the President on May 14, 1930. It was known in the Senate as the Ransdell bill, S. 3043 and in the House as the O'Connor bill, H. R. 8299.

The act authorizes the establishment of a National Hydraulic Laboratory in the Bureau of Standards, of the Department of Commerce and the construction of a building therefor. The laboratory is for the determination of fundamental data used in hydraulic research and engineering, including laboratory research relating to the behavior and control of river and harbor waters, the study of hydraulic structures and water flow and the development and testing of hydraulic instruments and accessories. The National Hydraulic Laboratory will be available to various activities of the Federal Government, also any state or political subdivision thereof, for the study of problems connected with projects the prosecution of which is under the jurisdiction of such state or political subdivisions.

The authorization carries with it an appropriation not to exceed $350,000 to be expended by the Secretary of Commerce for the construction and installation of a suitable hydraulic laboratory building and such equipment, utilities and appurtenances thereto as may be necessary.

A New Standard for Photometry and Illumination Symbols

Under the joint sponsorship of The American Association for the Advancement of Science, The American Society of Civil Engineers, the American Society of Mechanical Engineers, the Institute, and the Society for the Promotion of Engineering Education, a new standard in modification of the American Standard for Illuminating Engineering Nomenclature and Photometric Standards has just been adopted by the American Standards Association. A national standard for navigational and topographical symbols has also been approved as American Tentative Standard by the American Standards Association.

These standards are a part of a comprehensive program under the auspices of the American Standards Association for the unification of graphical symbols, symbols for quantities in equations and formulas, and of abbreviations as used in engineering and scientific reports, tables, and publications, but not including definitions of terms used in engineering and scientific practise. To date, the following proposals developed by the Sectional Committee have been approved as American Standard or as American Tentative Standard: symbols for hydraulics; symbols for telephone and telegraph use; symbols for photometry and illumination; aeronautical symbols; mathematical symbols; navigational and topographical symbols; letter symbols for electrical quantities.

New Type Welded Flooring Constructed in Pittsfield

An automatic arc welding machine, crawling along by its own power, has demonstrated its value in the construction of a new type of steel floor for buildings. The Wendell Garage, in Pittsfield, Massachusetts, is the first to use this machine on what is known as the "battledeck type of floor construction," representing a considerable saving in cost of erection.

The American Institute of Steel Construction is sponsor for this new kind of flooring, which was first announced at its convention of that body in Biloxi, Mississippi, November 14, 1929, Proponents of the method showed the new flooring involves much less weight than other types and is able to withstand every kind of service.

There was used a total of 193 separate plates each 2 feet wide by 20 feet long, making a total area of 40 x 160 feet, or 6400 square feet.

Deflection in the floor is very slight, and mostly in the center. Normally garages have floors built up in the center to drain water from ice-covered cars to side gutters. It was impossible to do this with the battledeck floor, so the center plate in each panel is cut out for a simple drain. This drain is connected with 1½-inch pipe on the ceiling below to the side wall, and drains to two feet above the gutter of the first floor.

Deflection occurred only under load, and there is 100 per cent recovery on removal of load. The floor is found to be clear and easily kept so; it is water tight and prevents any dripping on cars below.

Although the battledeck floor can be covered with any material such as cement, rubber tile, linoleum, cork, etc., it was unnecessary in the Pittsfield garage as the steel floor provided enough friction to prevent skidding.

The total storage capacity on the battledeck floor is 64 cars. The total capacity of the garage with the addition is approximately 500 cars.

The machine once started on a seam was almost entirely automatic in operation, following the seam accurately and feeding the electrode to the weld. About 30 min. were required to weld 20 ft. of the ¼-inch seam using 5/32-inch electrode.

Various types of welds are possible, but the one used at Pitts field was a flush weld presenting a smooth surface all the way across the entire floor. The welds not only join the steel plates but also weld them permanently to the I-beam below, making an unusually rigid joint and one which is very resistant to stresses of all sorts.

Federal Water Power Commission News

At the recent session of Congress, Public Law 412, Senate Bill 3619, was enacted which gave the President authority to appoint five commissioners to serve instead of the old commission which was composed of the Secretaries of Agriculture, Interior and War. Prior to the adjournment of the Senate on July 21, President Hoover nominated Marcel Garsaud, New Orleans engineer, for the three-year term; Ralph D. Williamson, attorney of Yakima, Washington, for the two-year term; and Claude L. Draper of Cheyenne, Wyoming, Chairman of the Public Service Commission of Wyoming, for the one-year term. Although these names were reported favorably by the Senate Committee on Interstate Commerce, due to the objection of Senate Walsh of Montana, the Senate adjourned without confirming them.

Pure Iron Electrodes Research

Upon the recommendation of the Electric Welding Committee of the Institute, the Board of Directors in May 1930 requested Engineering Foundation to sponsor a fellowship at Lehigh University for the purpose of advancing fundamental research in the electric welding art; the particular work to be basic studies on the properties of pure iron electrodes.

Engineering Foundation acted favorably upon this request and has accordingly made the necessary arrangements with the authorities at Lehigh University. The research will be conducted under the direction of Dr. Gilbert E. Doan of Lehigh University, who in a recent letter to Engineering Foundation outlined as follows the proposed work which will require about two years:

"An arc between pure iron electrodes has never been observed, to the best of my knowledge. If it were studied, say in an inert gas such as helium, it would then be possible to say how the customary impurities present in steel affect its weldability. For

instance, how do phosphorus and sulphur affect the arc welding properties of steel? How does carbon? How do manganese and silicon? These are questions of immediate interest among steel manufacturers, construction engineers and welding experts alike. Again, how do oxygen and nitrogen affect the welding properties of electrodes? How do non-metallic inclusions alter the properties? How do coatings influence the arc and the deposited metal? This basic work with pure iron will require time, careful arrangement of apparatus and a large number of measurements."

President Hoover Seeks Advice on Federal Power Commission

President Hoover has asked the Attorney General for a decision as to whether he has authority under the existing law, to make recess appointments to this Federal Power Commission in view of the fact that the Senate adjourned without confirming them. The Attorney General has presented his findings to the President but President Hoover has not yet disclosed them. It has been proposed that the three men whose names have been submitted be made special representatives of the three secretaries of Agriculture, Interior and War who now comprise the Commission, and that they act as such until confirmed by the Senate in December. In view of the failure of the Senate to confirm a working majority of the Commission, it is highly probable that the affairs of the Federal Power Commission will not be reorganized and stabilized as was intended by the reorganization measure, prior to the spring of 1931.

Doctor Hull Receives the Liebmann Memorial Prize

At the 1930, Toronto convention of the Institute of Radio Engineers the Morris Liebmann Memorial Prize was awarded to A. W. Hull, of the General Electric Laboratories, Schenectady, N. Y. This prize is awarded annually by the Institute of Radio Engineers, for meritorious achievement in radio science.

The prize, consisting of five hundred dollars in cash, was presented to Doctor Hull by Col. A. G. Lee, Vice-President of the Institute at the closing banquet of the convention. In response to the request of Vice-President Lee, Donald McNicol, Past-President of the Institute delivered a short and appropriate address. He said: "It is a pleasure for the officers of the Institute to award this prize to Doctor Hull. In the onward march of radio and in the literature of the art Doctor Hull's name has been a household word for years past. In the year 1906 when Doctor Lee de Forest delivered his memorable paper at a meeting of the A. I. E. E., describing the invention and operation of the audion, Professor M. I. Pupin, who was present, expressed his view that new, hybrid names should not be coined for attachment to electrical devices.

"In 1906, and for about a decade following that, the audion continued to be of nearly uniform size—about the same as that of present day radio receiving tubes. The employment of the tube as a generator of useful oscillations opened the way for larger dimensions in order to produce greater powers, with the result that today tubes are in use so large and bulky that two strong men have a task in carrying one of them safely.

"With these two features of the tube—its name and its size—Doctor Hull and his laboratory associates have had much to do in the years that have passed. Today, there are audions, radiotrons, magnetrons, dynatrons, plio-dynatrons, thyratrons, and there seems to be no end to the uses and the names which may be given to new applications of these electron devices.

"With the outstanding advances in the tube art, no man has had more to do than this year's recipient of the Liebmann prize—Doctor A. W. Hull, of Schenectady."

Scholarship in Electrical Engineering at West Virginia University

Those applying for this scholarship should have had a four-year course in Electrical Engineering in a recognized college or university and be able to give the usual recommendations required by graduate schools as to ability, character, fitness and interest.

The amount of money available for the fellowship is $1200.

Persons interested should communicate promptly with Dr. S. P. Burke, Head of the Graduate Council, West Virginia University, Morgantown, W. Va.

AMERICAN ENGINEERING COUNCIL

ADMINISTRATION BOARD MEETING

The Fall meeting of the Administrative Board of American Engineering Council will be held in Washington, October 17-18. President C. D. Grunsky will leave California the latter part of September.

AIRPORT DRAINAGE AND SURFACING COMMITTEES TO ORGANIZE

American Engineering Council jointly with the American Road Builders Association and Aeronautics Branch of the Department of Commerce, is conducting a study of airport drainage and surfacing. This study promises to render an unusual service to the engineering profession as well as to the public and the Federal agency charged with the responsibility of maintaining statistical information concerning airports. The development of airports is of such recent date and is playing such an important part in our present-day civilization, that it is felt there is need for the collection of handbook information upon this subject, and the involved problem can be adequately solved only by the employment of the most skilled engineering services from among engineers who have had experience in such matters. The Aeronautics Branch of the Department of Commerce maintains a list of consulting engineers who are available for such work and it will make the results of this study available to them and other engineers.

The Committee consists of:

Aeronautics Branch, Dept. of Commerce: Harry H. Blee, Director of Aeronautic Development, chr.; A. Pendleton Taliaferro, Jr., chief, Airport Section; John E. Sommers, airport specialist, secretary.

American Road Builders Association: Wm. A. Van Duzer, President of the American Road Builders Assn., and Asst. Chief Engineer of the Pennsylvania Highway Department, Harrisburg, Pa.; C. N. Conner, Executive Engineer of the American Road Builders Assn.; Col. C. E. Myers, President of the City Officials' Divn. of the Amer. Road Builders Assn., and Director of Transit, Philadelphia; Henry H. Wilson, Member of the Executive Board of the Associated General Contractors Division, and Managing Partner of Winston Brothers Company and H. H. Wilson, Harrisburg, Pa.; Charles M. Upham, Engineer-Director of the Amer. Road Builders Assn. and Executive Secretary of the Manufacturers' Divn.

American Engineering Council: W. W. Horner, Chief Engineer, Sewers and Paving, St. Louis, Mo.; Archibald Black, President, Black and Bigelow, Inc., Air Transport Engineers, New York City; Perry A. Fellows, City Engineer, Detroit, Mich.; C. A. Hogentogler, Senior Hwy. Engr., Bureau of Pub. Roads, Washington, D. C.; James H. Polhemus, Chief Engineer and Gen. Manager, The Port of Portland, Portland, Oregon.

A. E. C. AID-FOREST FIRE PROTECTION

American Engineering Council has accepted an invitation to have a representative serve on the committee organized by

the National Fire Protection Association in cooperation with the U. S. Forest Service and a number of other interested agencies. This committee is to direct its attention to the study of forest fire problems and to the correlation of existing activities in this field. Colonel W. B. Greeley, Secretary-Manager of the West Coast Lumberman's Association, Seattle, Wash., has consented to serve as American Engineering Council's representative on the proposed Committee on Forest Fire Protection.

KDKA to Use New 200-Kw. Tubes

Success of the new KDKA station being built near Saxonburg, Pa., will depend largely upon innovations in broadcast set design which have been developed by the radio engineering and research.

One of the most important of these is the new 200-kw. tube, not merely an enlarged edition of a smaller tube, but of distinctly novel design.

The new tube, called the AW-220, is 72 in. in height, has a diameter of eight inches and weighs 60 lb. In its design one of the greatest problems was the cooling of the grid but this difficulty was overcome by I. E. Mourmomtseff, a Westinghouse research engineer and an Associate of the Institute (1925), who through a double-end construction has produced a tube of mechanical strength and sturdiness.

The magnitude of the cooling problem may be appreciated from the statement that when in operation, approximately five tons of cooling water must pass through the water jacket of the tube each hour. This water cools the tube in the same manner in which an automobile motor is cooled. One hour's operation of the tube would heat the water supply of the average home for several weeks.

While these tubes will of course be used only to generate high-frequency power for radio stations, an appreciation of the power capacity of one of them may best be gained by a comparison with familiar household devices; for example, it would be sufficient to operate simultaneously four hundred toasters or flat irons which would also be the equivalent required to light one thousand average homes.

A. I. E. E. Directors Meeting

The regular meeting of the Board of Directors of the American Institute of Electrical Engineers was held at Institute headquarters, New York, on Tuesday, August 5, 1930.

There were present: President W. S. Lee, Charlotte, N. C.—Past President Harold B. Smith, Worcester, Mass.—Vice-Presidents W. S. Rodman, University, Va.; E. C. Stone, Pittsburgh, Pa.; C. E. Sisson, Toronto, Ont.; H. V. Carpenter, Pullman, Wash.; H. P. Charlesworth, New York, N. Y.—Directors F. C. Hanker, East Pittsburgh, Pa.; E. B. Meyer, Newark, N. J.; A. M. MacCutcheon, Cleveland, Ohio; C. E. Stephens, New York, N. Y.; A. B. Cooper, Toronto, Ont.; A. E. Knowlton, New York, N. Y.; R. H. Tapscott, New York, N. Y.; National Secretary F. L. Hutchinson, New York, N. Y.

The minutes of the Directors' meeting of June 25, 1930, were approved.

A report of the meeting of the Board of Examiners held July 15, 1930, was presented and approved. Upon the recommendation of the Board of Examiners, the following actions were taken; 9 Students were enrolled; 63 applicants were elected to the grade of Associate; 13 applicants were elected to the grade of Member; 81 applicants were transferred to the grade of Member: 8 applicants were transferred to the grade of Fellow.

Approval by the Finance Committee, for payment, of monthly bills amounting to $35,987.50, was ratified.

The following amendments and additions to the By-laws were adopted (to conform with the recent amendments to the constitution and action of the Board of Directors):

Section 51. First sentence cancelled and the following substituted:

Any person registered as a full-time student, graduate or undergraduate, in a university or technical school of recognized standing who is pursuing a regular course of study in preparation for the profession of electrical engineering may be enrolled as a Student of the American Institute of Electrical Engineers, except that a graduate student whose term of enrolment as specified in Section 53 has expired may not again enroll.

Section 53. Cancelled and the following substituted:

Sec. 53. The annual Student enrolment fee shall be three dollars ($3.00) payable in advance and shall cover the fiscal year of the Institute beginning on May first. The initial payment upon application for enrolment shall be on the basis of a full year's fee, three dollars ($3.00), or a half year's fee, one dollar and fifty cents ($1.50), depending upon whether the application is filed nearer to May first or November first respectively. The term of Student enrolment shall not extend beyond the end of the fiscal year in which Student status ceases.

Section 56-a. The following new section was inserted after Section 56:

Sec. 56-a. A Student must apply for admission to the Associate grade before the first of March of the fiscal year in which his Student status ceases in order to be relieved of the payment of the entrance fee, as provided for in the Constitution.

Section 82-a. The following new section was added:

Sec. 82-a. Each Technical Committee shall cooperate with similar committees of other organizations so that all concerned may be kept informed of related activities. Such cooperation however, shall not be permitted to limit the scope of Institute activities within the field of electrical engineering. No activity within the field of electrical engineering shall be relinquished for any reason if such activity is desirable in order that the Institute may completely serve all of its members. In case of doubt as to the proper scope of Institute activities, a ruling should be secured from the Board of Directors.

The Board voted to terminate officially the existence of the Washington and Lee University Branch of the Institute, which has been inactive for over a year.

The President announced the appointment of committees and representatives of the Institute for the administrative year beginning August 1, 1930. (A list of the committees and representatives appears elsewhere in this issue.)

As required by the By-laws of the Edison Medal Committee, the Board confirmed appointments to the Committee made by the President, as follows: Professor D. C. Jackson, as chairman for the year beginning August 1; Messrs. C. I. Burkholder, F. A. Gaby, and Harris J. Ryan for terms of five years each; Mr. F. A. Scheffler to fill unexpired term of Elmer A. Sperry, deceased. Also in accordance with the Committee's By-laws, the Board elected the following from its own membership to serve on the Committee: Messrs. A. E. Knowlton, Harold B. Smith, and R. H. Tapscott, for terms of two years each, and Mr. E. B. Meyer to fill a vacancy for the year ending July 31, 1931.

In accordance with the By-laws of the Lamme Medal Committee, the Board confirmed the appointment of the following members by the President: Messrs. Ralph D. Mershon, Julian C. Smith, and Percy H. Thomas, for terms of three years each, of Mr. R. B. Williamson to fill a vacancy, and of Professor Charles F. Scott as chairman for the year beginning August 1.

The following Local Honorary Secretaries were reappointed for the two-year term beginning August 1, 1930: W. Elsdon-Dew, Transvaal; H. W. Flashman, Australia; A. S. Garfield, France; F. W. Willis, India.

Recommendations adopted at the Conference of Officers and Delegates, in Toronto, in June, were considered and referred to appropriate committees.

Other matters were discussed, reference to which may be found in this and future issues of the JOURNAL

William Stanley Memorial

In memory of the late William Stanley, electrical pioneer and inventor, whose greatest contribution to electrical progress was the transformer, the William Stanley Memorial X-ray room was dedicated August 7 at the Fairview Hospital at Great Barrington, Mass. A large group of Mr. Stanley's friends was present at the simple exercises, and a brief address was delivered by Cummings C. Chesney, vice president of the General Electric Company and past president of the Institute, who was one of the original little group of assistants that worked with Stanley at Great Barrington and Pittsfield more than 40 years ago.

The memorial X-ray room represents a cost of $35,000 of which $10,000 was expended in providing the equipment, while the other $25,000 will constitute a perpetual endowment fund to maintain the room for the life of the hospital. The fund was contributed by 44 donors, all of whom were more or less intimately associated with Mr. Stanley during his career.

Two New Chairs for Aviation Education

Through the generous interest of the Western Air Express and the Richfield Oil Companies, two chairs of aviation education are being established at the University of Southern California, the Harris M. Hanshue Chair of Commercial Aviation, filled by Earl W. Hill, lecturer in the College of Commerce and Business Administration of S. C., and the James A. Talbot Chair of Aeronautical Engineering, filled by James M. Shoemaker, an aeronautical engineer of wide experience newly-appointed professor in the College of Engineering of S. C., assisted by Captain Douglas Keeney.

The Hanshue Chair makes possible for a student the pursuit of commercial aviation as a major subject in the College of Commerce and Business Administration of the University of Southern California, providing a professorship which will supply instruction in principles of commercial aviation, air transport management, airport management, commercial aviation problems, and aviation insurance.

The Talbot Chair presents a new course in aeronautical engineering following the regular mechanical engineering course for the freshman year. It introduces a class in aircraft shop into the program of mechanical engineering as early as the sophomore year; into the junior year, classes in airplanes and airships, meteorology, and principles of commercial aviation; and into the senior year, work in the aviation field such as aerodynamics, aircraft engines, aircraft communication, aircraft engine testing, propellers, aircraft engine design, aircraft structural design, airport management, and an aeronautics seminar, covering a study of current literature on aeronautical subjects.

Shop and laboratory courses are given at the flying field.

Louisiana Engineers Entertain Senator Joseph E. Ransdell

In recognition of his services to the engineering profession as evinced by his successful seven-year fight to secure a National Hydraulic Laboratory, the Louisiana Engineering Society gave a testimonial dinner in New Orleans, July 21, to Senator Joseph E. Ransdell. This event was of national significance, not only because it celebrated the enactment of a very constructive piece of legislation but also because it gave the professional engineers an opportunity to recognize and pay honor to a man who had successfully secured legislation which had been supported by the engineers of the United States through American Engineering Council since 1922.

PERSONAL MENTION

M. ELLIS JOHNSON has resigned his position as Head of the Electrical Engineering Department, University of Kansas, Lawrence, Kansas, to accept similar office with the Iowa State College at Ames, Iowa.

GEORGE RODWIN, who for the past five years has been with the Radio Corporation of America, is now connected with the Bell Telephone Laboratories, Incorporated, engaged in radio research and development work.

P. L. HOOVER, of the Case School of Applied Science has recently been named Associate Professor of Electrical Engineering, and Assistant Director of the Engineering Experiment Station, Rutgers University, and Delmar L. Cottle, of Ohio State University has accepted the office of Assistant Professor of Chemistry at Rutgers.

A. R. SMITH has been appointed Executive Engineer of the Turbine Engineering Department of the General Electric Company to succeed the late William J. Delles. Mr. Smith will retain his responsibility as engineer of the Construction Engineering Department. He has been with the General Electric Company since 1897, and with the Construction Engineering Department since 1908.

T. R. LANGAN, who has been with the Westinghouse Company for more than twenty years, has received appointment as Assistant Northeastern District Manager of the Westinghouse organization. He will make his headquarters at New York and will continue to function as Manager of the Transportation Division of the Northeastern District. His name has already been identified with the major high-voltage a-c. railroad electrifications in the United States, and when the New York, New Haven & Hartford Railroad system was electrified, acted in a supervisory capacity on this installation for seven years. Before coming to the New York office, Mr. Langan served the Westinghouse Company in Philadelphia, Baltimore, Buffalo and was manager of the Syracuse Office.

Obituary

William Kenneth Detlor, Transmission Engineer, Western Area of the Bell Telephone Company of Canada, Toronto, Ontario, died suddenly June 17, 1930. He became an Associate of the Institute in 1925. Mr. Detlor was born at Deseronto, Ontario, January 20, 1903; was a graduate of Queens University, 1922, with a degree of B. Sc. in Electrical Engineering, and with Mechanical Engineering in 1923. In 1920 he spent five months with the Canadian General Electric Company at Peterboro, winding and assembling transformers; from May to September 1922 he was associated with the Canadian Westinghouse Company at Hamilton, assembling and testing fans and general small motors; from October to November of the same year, as demonstrator in Electrical Engineering at Queen's University at Kingston, Ontario. In May 1923 he joined the Bell Telephone Company of Canada, entering the Engineering Department as Assistant to the Transmission Engineer, advancing thereafter to Transmission Engineer, the position he held at the time of his death.

Joseph Byron Rawlings, Patent Attorney for the Electrical Research Products, Incorporated, New York and London, died in London June 30, 1930. He was born at Mapleton, Monona County, Iowa, November 5, 1893 and acquired his general education in the public schools at Castana, Iowa. This he followed by technical course at Iowa State College, Ames, Iowa, where he took up Electrical Engineering, the opportunity coming to him by a scholarship from his work in high school and his

own earnings during holidays and college term. In 1916 he was graduated and became a student apprentice at the Iowa Telephone Company. This he followed by a year and a half as Electrical Assistant in the United States Signal Corps and further study of telephone systems as Assistant Electrical Engineer of the Bureau of Standards, Department of Commerce, Washington, D. C. Mr. Rawlings became an Associate the Institute in 1919. Since his affiliation with the European Patent Department of Electrical Research Products Incorporated he has been a resident of London, England.

Walter Hibbard Seaver, who has been Manager of Sales in the Wire Products Department of the United States Steel Products Company, Russ Building, San Francisco, California, for an extended time, died July 13, 1930, at his home in Oakland. He was sixty years old, and a native of Boston, Massachusetts, where his early education was obtained in the grade schools and the Boston High School, from which he was graduated in 1886. His record of service covers one year with Frye Phipps & Company, with whom he engaged September 1886; John Wales Company in 1887; Secretary of the National Wire Corporation during 1899; here he was made Vice-President and Secretary in May of 1905; November 1905 he joined the Sales Department of the American Steel & Wire Company, and through the manufacture and sale of telephone and telegraph wire became particularly interested in electrical matters, which led to a knowledge of all kinds of bars and insulated wire and cables of which his company were large producers. His interest extended also to rail bonds and all matters pertinent to electric railways in which his company was extensive as manufacturers; in fact everything connected directly or indirectly with the field of electricity was to him a matter for investigation and assimilation. He became an Associate of the Institute in 1907 and continued in this grade up to the time of his death.

John Joseph Lyng, Vice-President of the Electrical Research Products Incorporated, New York, N. Y., died suddenly August 9, from over exertion in an effort to rescue his sister-in-law who was caught in the undertow while bathing near the foot of Beach 145th Street. He was a native of Carbondale, Pennsylvania and his General and Technical education was gained by attendance at public school and evening study. He took no regular courses, but acquired experience by continuous study of standard works and the reading of technical articles, carefully scrutinizing all developments and absorbing knowledge from practical contacts. In 1902 he joined the New York Telephone Company on installation work; from 1903 to 1905 was Superintendent of the Couch & Seeley Company, Telephone Manufacturers, Boston, Massachusetts, and then joined the Western Electric Company, first as Central Office Equipment Engineer; then in apparatus development work, and in 1907, in charge of Apparatus Development,—especially the development of telephone equipment. He held positions carrying great responsibility, directing a large force of engineers engaged in the design and development of manual and machine switching central office equipment and line apparatus. He was also engaged in the development of important radio innovations. During the war he was actively busy in Government projects and carried through this work with great credit to himself and the Bell System. He became a Member of the Institute in 1923. His various appointments in the profession called him to work of high executive responsibility.

Ira Nelson Hollis, Past-President of Worcester Polytechnic Institute and also Past-President of The American Society of Mechanical Engineers, died at his home in Cambridge shortly after midnight August 15th after a brief illness of only a few hours. He was 74 years old and his was an unusual and distinguished career, even his early life containing much of extraordinary interest. Born at Mooresville, Indiana, March 7, 1856, he was first educated in the city schools of Louisville, Ky. As an apprentice, he entered a local machine shop for building and repairing engines, particularly those of the Ohio River steamboats, but his health was not equal to the undertaking and he secured an office position with the railroad company, later changing to service with a cotton commission house in Memphis. While still a clerk in the railroad company's office, he learned of an examination which was being given for admission to the Naval Academy at Annapolis. These tests were held at Annapolis and he aspired to candidacy by perseverence. Thus far his experience had not even given him a grounding on the subjects involved; he was only an ill clothed boy of 18 when he finally located the Navy Department building and entered it by a rear door. No one was about, but, he discovered the office of the Secretary of the Navy. Had he entered by the regular entrance and been compelled to disclose his errand, he might have failed in the audience he was seeking and his undertaking; but the Secretary was interested, and gave the boy the papers necessary for him to present at Annapolis, Hollis returned to Louisville and waited for the hoped for orders to report to the Naval Academy. His acceptance was one of 25 cadets out of the 125 who competed. Another railroad pass took him to the Academy where he presented himself to the Commandant. That officer took his order to check with the list, and after three times passing down the column of 25 names, said, "There has been some mistake; your name is not listed." But young Hollis insisted, and in making a final search, the officer lifted his hand from the top of the paper and there, heading the list was Ira Nelson Hollis. Thus started a brilliant carrer in the Navy. Shortly after his three years on the *SS. Charleston*, a call came to Rear Admiral Melville, Engineer-in-Chief of the Navy, to designate an officer to lecture on naval engineering at the Naval War College. He chose Doctor Hollis, whose lectures immediately attracted so much of unusual attention that they were published later in textbook form. He was then appointed Assistant to Frank H. Bailey, Chief Designer of the Navy, and was slated to become head of that department. His last work for the Navy was the preparation of specifications for the machinery of the gunboat *Nashville*, and the design of machinery for torpedo boats. In 1893 Harvard University claimed his service as Professor of Engineering, and on the recommendation of the Secretary of the Navy, Rear Admiral Sampson, and Rear Admiral Melville, he was invited to accept a Chair in the Harvard Faculty. At the end of two years, he was made Chairman of the Harvard Athletic Committee, and soon was of wide repute as the builder of the Harvard Stadium, its design and construction being accomplished under his personal direction. He was also Chairman of the Committee which raised funds for the Harvard Union and under his supervision, that building also was erected. A few years after Doctor Hollis's advent at Harvard, President Eliot designated him as "the greatest find in 25 years." In 1913 he resigned from Harvard to accept the presidency of Worcester Polytechnic Institute, where his success was again widely recognized. While at Worcester, he was elected President of the American Society of Mechanical Engineers, and as such rendered invaluable service in both practical and professional fields. His work for industrial preparedness has attracted widespread attention. Harvard conferred upon him the honorary degree of Master of Arts, in 1899, from Union College he won a degree of L. H. D., also in 1899; and his degree of Doctor of Science from the University of Pittsburgh in 1912. He was a Fellow of the American Academy of Arts and Sciences, member of the Society of U. S. Naval Engineers, the American Society of Naval Architects and Marine Engineers, the Boston Society of Civil Engineers and the Society for the Promotion of Engineering Education, the American Society of Civil Engineers, the Massachusetts Military Historical Society; Overseer of Harvard University, Trustee of the Worcester Polytechnic Institute Clubs and also of the Worcester and Boston Engineers Clubs and of Boston University.

Engineering Societies Library

The Library is a cooperative activity of the American Institute of Electrical Engineers, the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers and the American Society of Mechanical Engineers. It is administered for these founder societies by the United Engineering Society, as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West Thirty-ninth St., New York.

In order to place the resources of the Library at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies or translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Library maintains a collection of modern technical books which may be rented by members residing in North America. A rental of five cents a day, plus transportation, is charged.

The Director of the Library will gladly give information concerning charges for the various kinds of service to those interested. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

The library is open from 9 a. m. to 10 p. m. on all week days except holidays throughout the year except during July and August, when the hours are 9 a. m. to 5 p. m.

BOOK NOTICES, JULY 1-30, 1930

Unless otherwise specified, books in this list have been presented by the publishers. The Institute does not assume responsibility for any statement made; these are taken from the preface or the text of the book.

All books listed may be consulted in the Engineering Societies Library.

L'Appareillage Électrique.

By Louis Lagron. Paris, Albert Blanchard, 1930. 587 pp., illus., diagrs., 7 x 5 in., paper. 36.-fr.

The theory, construction and applications of switchgear are described in this general survey of the subject. Apparatus for both high and low voltages is covered, and a great variety of commercial types is treated.

Bacteriology; a textbook on fundamentals.

By Stanley Thomas. 2nd edition. N. Y., McGraw-Hill Book Co., 1930. 301 pp., illus., 9 x 6 in., cloth. $3.00.

Sets forth the essential principles of the subject and discusses its applications in engineering, agriculture and the food industries. The book gives the fundamentals needed by engineers interested in water supply and sewage disposal.

Les Applications des Rayons X; Physique, Chimie, By Métallurgie.

By J. J. Trillat. Paris, Les Presses Universitaires de France, 1930. (Recueil des Conférences-Rapports de Documentation sur la Physique, v. 17). 298 pp., illus., diagrs., 10 x 6 in., boards. 85.-fr.

Modern applications of X-rays in the study of physico-chemical and industrial questions are summarized intelligently in this work, and good bibliographies are included. The study of states of matter, of metals, cellulose, colloids, rubber, gelatine, and other chemical substances is described, with emphasis upon very recent work. The general properties of the rays and the methods of producing and using them are given briefly in the introduction to the work.

Condensed Chemical Dictionary. 2nd edition. N. Y., Chemical Catalog Company, 1930. 551 pp., 9 x 6 in., cloth. $10.00.

Gives the salient facts, such as the composition, source, properties and principal uses, for a great number of the chemicals and chemical products ordinarily met with in commerce. The fire hazard of each, the containers used and the railroad shipping regulations are also given. The book provides the information wanted so often by purchasing agents, manufacturers and others who are not trained in chemistry. Many trade names are defined.

Contributions to the History of Science.

By Louis Charles Karpinski and John Garrett Winter. Ann Arbor, University of Michigan, 1930. (University of Michigan Studies. Humanistic series, v. 11). 283 pp., port., facsims., 11 x 8 in., cloth. $3.50.

Contains two monographs of value to historians of science. The first, by Professor Karpinski, upon Robert of Chester's Latin translation of the Algrebra of Al-Khowarizmi, contains the Latin text and an English translation with notes, with a valuable essay upon the great Arab mathematician and his translator, and their influence upon the development of mathematics. The second monograph, by Dr. Winter, contains an English translation of Steno's Prodromus, with a life of this great geologist. The book is a valuable addition to our information on early science.

Cost Finding for Engineers.

By Charles Reitell and Clarence Van Sickle. N. Y., McGraw-Hill Book Co., 1930. 518 pp., forms, 9 x 6 in., cloth. $5.00.

A textbook intended to give students of engineering a working knowledge of cost finding. The basic principles of general accounting technique, the fundamentals of asset valuations, the use of control accounts, and the processes of unit product cost finding are set forth, giving the necessary background for higher cost-finding procedure. Those phases of general accounting which are only indirectly related to the problems of engineering are omitted.

Development of the Federal Program of Flood Control on the Mississippi River.

By Arthur De Witt Frank. N. Y., Columbia University Press, 1930. (Studies in history, economics and public law . . . No. 323). 269 pp., 9 x 6 in., cloth, $4.25.

Traces the part played by the Federal government in the efforts to control the Mississippi, showing the development of the ever increasing program, and discussing the forces that have aided or hindered this development. The engineering problem and the methods of flood control which have been advanced are described only as they have affected the development of this program. A full bibliography is included.

Diesel Engine Operation, Maintenance and Repair.

By Charles H. Bushnell. N. Y., John Wiley & Sons, 1930. 285 pp., illus., diagrs., tables, 9 x 6 in., cloth. $3.50.

A clearly written, concise discussion from the point of view of the operating engineer. Fundamental principles are emphasized and much practical information and advice given.

DIE ELEKTRISCHE KRAFTÜBERTRAGUNG, v. 1; Die Motoren, Umformer und Transformatoren.

By Herbert Kyser. 3rd edition. Berlin, Julius Springer, 1930. 544 pp., illus., plates, diagrs., 9 x 6 in., cloth. 36.-r. m.

Beginning with the equipment for utilizing electric energy, this treatise treats of the whole field of transmission, transforming, converting, line construction and power plants. The present volume is devoted to motors, converters and transformers. The characteristics of these machines, their connections, their uses and their types are described quite in detail, with methods for comparing efficiencies. The work is non-mathematical and practical, theoretical matter being used only where necessary to explain practical points.

ELEKTROTHERMIE; Die Elektrische Erzeugung und Technische Verwendung Hoher Temperaturen. Edited by M. Pirani. Berlin, Julius Springer, 1930. 293 pp., illus., diagrs., tables, 9 x 6 in., bound. 36.-r. m.

Lectures by specialists on the electrothermy of iron; electric melting furnaces for non-ferrous metals; the manufacture of silicon carbide, carborundum and alumina cement; artificial graphite; calcium carbide factories; fused quartz; the electrothermy of gases; electrothermal research work; and measuring instruments and processes. These were delivered in 1928 at an institute organized by the Vienna Technical High School.

ENGINEERING KINEMATICS.

By William Griswold Smith. 2nd edition. N. Y., McGraw-Hill Book Co., 1930. 343 pp., illus., diagrs., tables, 9 x 6 in., cloth. $3.50.

The fundamental laws governing the conversion and transfer of motion, and the ways in which these principles are applied to the design of machines, are here presented, with as much emphasis upon practical applications as the limits of a textbook permit. Many problems are given. The new edition is partly rewritten and brought up to date.

FORSCHUNG UND TECHNIK; Im Auftrage der Allgemeinen Elektricitäts-Gesellschaft. Edited by W. Petersen. Berlin, Julius Springer, 1930. 576 pp., illus., 12 x 9 in., bound. 40.-r. m.

This book gives an insight into the scientific research that is being carried on in research institutes and by large industrial organizations. Specifically, it contains some forty papers upon present problems in various branches of physics, electrical engineering, machine design and transportation, based on recent work of the Allgemeine Elektrizitaets Gesellschaft, Berlin, ndd written by members of its research staff. The contents of the book cover a wide range and illustrate clearly the advantages to industry of systematic scientific research.

GEFÄLLVERMEHRUNG BEI NIEDERDRUCK-WASSERKRAFTANLAGEN.

By Rudolf Gelbert. (Mitteilungen aus dem Gebiete des Wasserbaues und der Baugrundforschung, heft 2). Berlin, Wilhelm Ernst & Sohn, 1930. 22 pp., illus., diagrs., tables, 11 x 7 in., paper. 3,60 r. m.

Presents the results of tests of a method of increasing the head of low-pressure hydraulic turbines proposed by Dr. John R. Freeman. This method consists in introducing part of the surplus water, escaping over the dam, into the draft tube of the turbine, where it reduces the discharge pressure and thus increases the effective head.

GERMAN-ENGLISH TECHNICAL AND SCIENTIFIC DICTIONARY.

By A. Webel. N. Y., E. P. Dutton & Co., 1930. 899 pp., 10 x 7 in., cloth. $10.50.

This new German-English dictionary contains, it is stated, about 75,000 words. These are largely chemical, botanical and mineralogical terms, and the dictonary will be especially useful to those engaged in the chemical industries and in medicine. Useful appendixes are a long list of common German abbreviations and a glossary of botanical terms with German and English equivalents. The volume is printed in very readable type and is of convenient size.

GRUNDLAGEN UND ENTWICKLUNG DER ENERGIEWIRTSCHAFT OSTERREICHS.

By Oskar Vas. Wien, Julius Springer, 1930. 189 pp., illus., map, tables, 11 x 8 in., paper. 20.-r. m.

A comprehensive report on the power resources of Austria and their organization, prepared for the World Power Conference at Berlin. The development of the fuels, water powers, and electricity is covered in full, the power organization of the railroad system is described, and the laws relating to water and electricity are given. A map shows coal mines and power plants.

HIGH VOLTAGE OIL CIRCUIT BREAKERS.

By Roy Wilkins and E. A. Crellin. N. Y., McGraw-Hill Book Co., 1930. 301 pp., illus., diagrs., tables, 9 x 6 in., cloth. $4.00.

Presents the salient characteristics and advantages of the principal types of oil circuit breakers, including late high-voltage models. The underlying theory and methods of testing are also discussed, and a brief history of high-voltage switches and circuit breakers is included.

INCREASING THE RECOVERY OF PETROLEUM.

By Wentworth H. Osgood. N. Y., McGraw-Hill Book Co., 1930. 2 v., illus., diagrs., tables, 9 x 6 in., cloth. $10.00.

A compact summary of the information available on methods for increasing the recovery of petroleum from known fields. Existing conditions are discussed briefly, with the nature of reservoirs, the fluids involved and the theory of normal production. The major part of the work is then devoted to an exposition of the hydraulics of oil-well flow, the thermodynamics of oil wells, and to a description of practical methods for increasing recovery and their success in various fields.

DER INDUSTRIELLE WÄRMEÜBERGANG.

By Alfred Schack. Düsseldorf, Verlag Stahleisen, 1929. 411 pp., 8 x 6 in., cloth. 18,50 r. m.

A practical textbook for engineers, based upon the investigations of the Verein deutscher Eisenhüttenleute. Radiation, convection and conduction are discussed at length, the calculation of recuperators and regenerators is explained and the use of the theory of heat transmission illustrated by numerous practical examples. Throughout the work an effort is made to develop simple formulas that can be applied readily to practical problems.

JAHRBUCH DER DEUTSCHEN GESELLSCHAFT FÜR BAUINGENIEURWESEN, 1929. v. 5. Berlin, V. D. I. Verlag, 1930. 216 pp., illus., port., map, plates, 8 x 6 in., paper. 12.-r. m.

In addition to the membership list and other data usually found in the yearbooks of societies, there are several valuable papers on unusual subjects, and useful reviews of recent activities in construction. Papers are included on port warehouses, methods of tunneling for hydraulic power plants, and the forms of steel bridges. Other inclusions are a review of progress in building materials and their testing, a list of the important magazines devoted to civil engineering, statistics of students of civil engineering in German schools, and a useful list of the large bridges, buildings, waterworks, sewerage systems, railroads and hydraulic power plants built in Germany and Austria during 1929.

JAHRBUCH DER ELEKTROTECHNIK, 1927.

Edited by Karl Strecker. Berlin, V. D. I. Verlag, 1929. 284 pp., 10 x 7 in., cloth. 15.-r. m.

This volume of this well-known bibliography gives a review of the periodical literature of electrical engineering for the year 1927. The summaries review the advances of the year quite thoroughly, and the author and subject indexes are very full. The present volume is the last that will appear.

MATTER AND RADIATION; with particular reference to the detection and uses of the Infra-Red Rays.

By John Buckingham. N. Y., Oxford University Press, 1930. 144 pp., 9 x 6 in., cloth. $3.00.

Starting with an account of electric waves, the author proceeds to a consideration of atoms and molecules, and the electrical structure of atoms and the production of radiation. The final two chapters treat the detection and uses of infra-red rays. The work is non-mathematical and devoid of unnecessary technicalities, so that it is understandable by the non-scientific reader. The author is Assistant Director of Scientific Research for the British Admiralty.

MECHNICAL ENGINEERS' HANDBOOK. Edited by Lionel S. Marks. 3rd edition. N. Y., McGraw-Hill Book Co., 1930. 2264 pp., diagrs., tables, 7 x 5 in., fabrikoid. $7.00.

In preparing the new edition of this well-known work of reference, especial attention has been paid to the increasing importance of a knowledge of the fundamental theory underlying the design and operation of machinery. Theoretical discussions have been strengthened and new sections added on such important subjects as vibration and dimensional analysis. Standards and practise have been brought up to date, and physical data have been revised. New sections have been added, making the book nearly three hundred pages longer. The new edition will be welcomed warmly by engineers.

MODERN PHYSICS; a general survey of its principles.

By Theodor Wulf. Translated from the 2d German edition by C. J. Smith. N. Y., E. P. Dutton & Co., 1930. 469 pp., 10 x 6 in., cloth. $10.00.

The educated reader in search of an account of physics will find his needs fully met by this admirable coordinated account of its fundamental results. The style is clear, non-mathematical and readable. The leading facts are clearly brought out and technicalities and small details are avoided. Those who wish to become acquainted with the results of physics, or who must utilize and consider them in their daily work, will welcome this survey.

OSTERREICHS ZUKÜNFTIGE ENERGIEWIRTSCHAFT.

By Richard Hofbauer. (Osterreichisches Kuratorium für Wirtschaftlichkeit. Veröffentlichung 2). Wien, Julius Springer, 1930. 87 pp., diagrs., maps, tables, 8 x 6 in., paper, 2,80 r. m.

A report on the probable development of power utilization. The available sources of energy—coal, oil, wood and water are appraised, the future requirements of the various industries are estimated, and the best methods of utilizing the available power are discussed.

PLANT LOCATION.

By W. Gerald Holmes. N. Y., McGraw-Hill Book Co., 1930. 275 pp., maps, tables, 9 x 6 in., cloth. $3.00.

The author has endeavored to outline a logical plan for investigating the desirability of different locations and to indicate a method for evaluating them. The choice of a general region, of a community, and of a site are considered in turn, and the factors to be considered, with the dangers to be avoided, are discussed.

PROTECTION OF WORKERS OPERATING METAL-WORKING PRESSES. (Studies & Reports, Series F, 2d Section, Safety, No. 4). Geneva, International Labour Office, 1930. Distributed in the U. S. by the World Peace Foundation, 40 Mt. Vernon St., Boston, Mass. 123 pp., illus., 9 x 6 in., paper. $1.25.

Describes safety devices for various types of presses which have been found satisfactory through actual use.

RAPID METHODS FOR THE CHEMICAL ANALYSIS OF SPECIAL STEELS, STEEL-MAKING ALLOYS, THEIR ORES, GRAPHITES AND BEARING METALS.

By Charles Morris Johnson. 4th edition. N. Y., John Wiley & Sons, 1930. 729 pp., illus., tables, 9 x 6 in., cloth. $7.50.

This well-known manual for the steel-works chemist has been enlarged and revised by the addition of nearly two hundred pages of new methods and modifications of old ones. Methods are given for handling all the materials that are usually met in the laboratories of makers of special steels. The directions are full and specific.

TEXTBOOK OF THE MATERIALS OF ENGINEERING.

By Herbert F. Moore. 4th edition. N. Y., McGraw-Hill Book Co., 1930. 409 pp., illus., diagrs., tables, 9 x 6 in., cloth. $4.00.

A concise elementary presentation of the physical properties of the common materials, with brief descriptions of their manufacture and uses, intended as a textbook for technical students. In the new edition several chapters have been rewritten and a new one, on the crystalline structure of metals, added. Other parts of the book have been extended and revised.

THEORY OF THE POTENTIAL.

By William Duncan MacMillan. N. Y., McGraw-Hill Book Co., 1930. 469 pp., 9 x 6 in., cloth. $5.00.

Designed for students of mathematics and of mathematical physics, this book is intended to give a connected account which will serve as an introduction to the subject and stimulate the cultivation of this useful field of mechanics.

WATER SUPPLY AND UTILIZATION.

By Donald M. Baker and Harold Conkling. N. Y., John Wiley & Sons, 1930. 495 pp., illus., maps, diagrs., tables, 9 x 6 in., cloth. $6.00.

The important results of the extensive research work on hydrology which has been done during the past quarter of a century is presented here in systematic form. The book is written from the viewpoint of the arid regions of the West, and illustrated by practise in that region. A summary of water law as enacted in the western states is included. Bibliographies accompany the chapters.

COMPREHENSIVE TREATISE ON INORGANIC AND THEORETICAL CHEMISTRY, v. 10.

By J. W. Mellor. N. Y., Longmans, Green & Co., 1930. 958 pp., 10 x 6 in., cloth. $20.00.

The tenth volume of this great treatise affords an exhaustive account of the chemistry of sulphur and selenium, upon a scale never attained in any other work in English. Dr. Mellor has compressed everything known about these elements into some nine hundred pages, forming a work that will be indispensable to every chemist. Numerous long bibliographies add to the value of the book.

DAS BUCH DER GROSSEN CHEMIKER, Bd. 1.

By Günther Bugge. Berlin, Verlag Chemie, 1929. 496 pp., illus., ports., facsims., 9 x 6 in., cloth. 24.-r. m.

The aim of this book is to present a series of interconnected biographies of great chemists which will give the reader a survey of the entire history of chemistry. The list begins with Zosimos, who lived about 400 B. C., and ends with Schoenbein, who died in 1868. Many eminent chemists are contributors of essays. The book is interesting reading, contains portraits of the chemists treated and gives an admirable account of the evolution of chemistry and the men who advanced it.

A. I. E. E. SECTION ACTIVITIES

NEW YORK SECTION OCTOBER MEETING DATES

A tentative schedule of meeting dates for the first meetings of the new administrative year 1930-31 has been set for October, as follows: Power Group, Wednesday, October 8th; Communication Group, Tuesday, October 14; General Section meeting, Friday, October 24th. Complete details will appear in the October JOURNAL and in notices to be mailed to the Section membership.

A PUBLIC SPEAKING CLASS PLANNED

A public speaking class is being arranged by the Power Group of the New York Section to begin this Fall. Any member of the Section will be welcome to participate. Section members interested are asked to send in their names now. This will help the committee to make adequate arrangements. Just send a brief note signifying your interest, and complete particulars will be sent you when final arrangements for the Fall are made. Address your letter to L. E. Frost, Chairman, Public Speaking Class Committee, New York Section A. I. E. E., 33 West 39th St., New York, N. Y.

Engineering Societies Employment Service

Under joint management of the national societies of Civil, Mining, Mechanical and Electrical Engineers cooperating with the Western Society of Engineers. The service is available only to their membership, and is maintained as a cooperative bureau by contribution from the societies and their individual members who are directly benefited.

Offices:—31 West 39th St., New York, N. Y.—W. V. Brown, Manager.

1216 Engineering Bldg., 205 W. Wacker Drive, Chicago, Ill., A. K. Krauser, Manager.

57 Post St., San Francisco, Calif., N. D. Cook, Manager.

MEN AVAILABLE—Brief announcements will be published without charge but will not be repeated except upon requests received after an interval of one month. Names and records will remain in the active files of the bureau for a period of three months and are renewable upon request. Notices for this Department should be addressed to ***EMPLOYMENT SERVICE, 31 West 39th Street, New York City,*** *and should be received prior to the 15th day of the month.*

OPPORTUNITIES.—A Bulletin of engineering positions available is published weekly and is available to members of the Societies concerned at a subscription of $3 per quarter, or $10 per annum, payable in advance. Positions not filled promptly as a result of publication in the Bulletin may be announced herein, as formerly.

VOLUNTARY CONTRIBUTIONS.—Members obtaining positions through the medium of this service are invited to cooperate with the Societies in the financing of the work by contributions made within thirty days after placement, on the basis of one and one-half per cent of the first year's salary: temporary positions (of one month or less) three per cent of total salary received. The income contributed by the members, together with the finances appropriated by the four societies named above will it is hoped, be sufficient not only to maintain, but to increase and extend the service.

REPLIES TO ANNOUNCEMENTS.—Replies to announcements published herein or in the Bulletin, should be addressed to the key number indicated in each case, with a two cent stamp attached for reforwarding, and forwarded to the Employment Service as above. Replies received by the bureau after the positions to which they refer have been filled will not be forwarded.

POSITIONS OPEN

DESIGNING ENGINEER, for fractional hp. motors. Apply by letter stating education, previous experience, age and salary expected. Location, Middle west. W-1461-C.

MECHANICAL AND ELECTRICAL CONSULTANT, graduate engineer, American, familiar with inside and outside equipment for non-ferrous and precious metal mines. Apply by letter. Location, Europe. W-1570.

LABORATORY ENGINEER OR PHYSICIST for industrial laboratory dealing with electrical and physical measurements. Extensive experience with electrical measuring devices and with materials and methods used in the making of fine electrical instruments, desired. Must possess some executive ability and have a reasonably good personality. The range of work is unusually great. Opportunities for advancement. Apply by letter. Location, New England. W-1582.

ENGINEERING ORGANIZATION has opportunity for technical graduate with several years' experience in the electrical industry, for position involving preparation of material for publication, including abstracts of engineering reports and other editorial work. Apply by letter stating age, education, and experience in detail. Location, New York. W-1177.

MEN AVAILABLE

ESTIMATOR AND APPRAISER, 15 years' experience with largest concerns. Graduate electrical and mechanical engineer, M. A. degree, age 40, executive ability, now employed. C-3260.

ELECTRICAL ENGINEER, age, 33, married. Graduate Ohio State University. Five years with municipality as Chief Electrical Inspector, supervising all electrical installations. Nine years' practical experience journeyman electrician. Two years' supervision, four Government Airmail Airways projects; knows designing and specifying engineering projects; good estimator; long experience in shop and as executive. C-7801.

ENGINEER, twenty years' experience on location, design, construction and operation of steam and hydroelectric power plants. Specialist on economics of power plants. Speaks Spanish. Glad to go abroad. Available now. A-3494.

GRADUATE ENGINEER, 27, married, experienced in low-tension distribution practise, planning and supervising sale of Mazda lamps and general lighting equipment. Desires work in associated lines under competent older engineer or manager. Available on two weeks' notice. C-7819.

ELECTRICAL ENGINEER, (E.E. and Ch.E.), 34 years old, married, with ten years of diversified experience in construction and public utility practises is available for new engagement at short notice. For the past three years employed in administrative position with large eastern utility company. C-658.

ENGINEER, B. S. E. Ten years' experience in construction, maintenance, and operation of electrical equipment. Desires new connection with responsibility. Best of references and available on short notice. Prefers western, midwestern or southern location, B-2865.

ELECTRICAL ENGINEER, Bachelor's and professional degrees. One and one-half years of research, six and one-half years of teaching, for the past three years head of department in State university. Age, 32, married. Desires any position for which experience will qualify. B-7263.

UTILITY ENGINEER, rate revision for increased revenue analysis and reduction of operating expenses. Gas, electric, and water appraisals, field and office work. Have qualified in commission and federal courts. Twenty years' experience, age 40, married. East preferred. B-6090.

ELECTRICAL ENGINEERING GRADUATE of the class of 1929 desires position with large power and light company, or with large gas company in the South or Southwest. At present employed by large eastern railroad company working on electric locomotives and electric cars. Can report on two weeks' notice. C-7856.

ELECTRICAL ENGINEERING TEACHER, nine years' teaching experience. Wants position above the grade of instructor where an opportunity can be had of completing work for doctor's degree. Have M. S. degree, am Member of A. I. E. E. and have had G. E. Test as well as teaching and research experience. B-660.

PUBLIC UTILITY ENGINEER, graduate of Mass. Inst. of Tech., with Master's degree in Electrical Engineering, desires position of responsibility with an engineering, financial, or utility concern where he can apply his twenty years' economic, financial and managerial experience. Now employed. Available on customary notice. Eastern location preferred. C-5280.

ELECTRICAL DESIGN DRAFTSMAN, 30, single, third year night engineering, twelve years' experience covering design of power plants, substations, and network systems. Desires connection with public utility. Location immaterial. At present employed. Available on two weeks' notice. B-8628.

GRADUATE ELECTRICAL ENGINEER. Seven years' experience in railway (car equipment) engineering and test work, and seven and one-half years selling railway equipment and supplied. Either type of work desirable but preferably the latter. Excellent record and wide acquaintance in New York Metropolitan District. Would consider account as manufacturer's agent. Available at once. B-4808.

SUPERINTENDENT, age 40, electrical construction and maintenance. 15 years' experience with large manufacturer of car dumpers, cranes, bridges, and all types of coal and ore handling machinery. C-7873.

ELECTRICAL ENGINEER, married. A. B. in mechanical engineering. Ten years' experience including civil, mechanical, electrical and radio engineering, design and manufacture of radio transmitters, and development of new systems for remote control and automatic attendance of electrical apparatus. C-7876-308-C-1.

ELECTRICAL GRADUATE, B. S. degree, 30, married. Two years Westinghouse transformer test, four years' public utility experience. Experience covers organization, teaching linemen's school, design of construction equipment, testing construction materials, construction estimates, various cost account reports, cable layouts, standard construction drawings. Executive ability. Desires permanent position with growing organization. C-7867.

ELECTRICAL ENGINEER with lengthy experience in survey, design, construction, maintenance, and accounting for overhead distribution and underground transmission using network secondaries; previously in industrial and railroad electrification. Desires position as budget or distribution engineer. C-7096.

1930 GRADUATE ELECTRICAL ENGINEER, single, 24, desires position in a steel mill or with some utility company that sells power to large industrial concerns. Will accept other work. Location, immaterial. C-7880.

1929 GRADUATE ELECTRICAL ENGINEER, 24, single, 14 months on General Electric test course. Desires location with utility or engineering work with manufacturing company in the South. Also interested in instructorship in a southern college. Hard worker. C-7881.

ELECTRICAL APPLIANCE ENGINEER thoroughly experienced in design of electric ranges, domestic appliances and electric heating elements. B. S. degree in electrical engineering from Purdue University. Age 26. Desires responsible position with manufacturer of the above type of equipment as designing or manufacturing engineer. Location, immaterial. C-7887.

ELECTRICAL ENGINEER, age 26, now employed. Four years' experience in maintenance of way work on railroads covering engineering, construction, maintenance and valuation of signals and signal systems, and six months in the non-destructive testing of rails for internal failures. Desires a more permanent location. C-7729.

TECHNICALLY TRAINED ELECTRICAL ENGINEER with 20 years' experience in electric distribution engineering and executive positions of responsibility, desires to locate with public utility in East or Middle west. Would also consider position where experience in radio engineering could be acquired. Best of references and services available immediately. C-7700.

ELECTRICAL ENGINEER, 32, married, nine years' general testing and development experience, including railway equipment with exceptional practical knowledge of power mercury arc rectifiers. Desires position in test or operating departments of public utility or electric railroad, South, East, or Chicago. C-7875.

DISTRIBUTION, DESIGN, OR RESEARCH ENGINEER, professor or instructor. B. S. in engineering, Johns Hopkins University. M. S. in E. E., University of Illinois, thesis on transformer reactance. Five years Assistant in Electrical Engineering, University of Illinois, two years Westinghouse student and tester, four years distribution design, Duquesne Light Company, Pittsburgh, Pa. B-2758.

ELECTRICAL ENGINEER, 27, married. One year's experience in cable manufacturing and research and four and one-half years with large rapid transit company. Now employed. Experienced on various power cables up to 132-kv. underground and overhead transmission. Desires new connection, location immaterial. Available on short notice. C-4420.

ELECTRICAL, STEAM, AND MECHANICAL ENGINEER, 33, married, 12 years' experience in industrial plants, supervising for the past eight years. Present job expires October 1st. B-7004.

ELECTRICAL ENGINEER, 24, single, graduate Pratt Institute, 1926. Practical experience, research metals refining company, power plant and substation testing, servicing and sales of high frequency machines, production clerk, inspecting machined parts. Desires position with responsibility and possibilities for advancement. Location, anywhere. Available on short notice. C-3160.

MECHANICAL AND ELECTRICAL ENGINEER, married. Degrees here, and Doctor, German for research. Fifteen years connected and in charge purchasing, sales and export office handling materials every possible description in large amounts. Available because company closed. Wide business experience. Linguist. Adaptable to any position outside those mentioned. C-7823.

INSTRUCTOR to teach D. C. and A. C. classes and laboratory. Position desired by university graduate with five years' practical experience, 3 years' graduate work in engineering and business administration, but congenial personality is greatest asset. Linguistic qualifications: German and French. Special aptitude for teaching. C-930.

ELECTRICAL ENGINEER, 40, married. Graduate Cornell University. Also A. B. degree De Pauw University. Eight years' public utility experience, four years manager of property. Experienced in preparation of appraisals, budgets, financing and general management problems. Also has had experience testing motors, electric meters and in telephone transmission. Available at once. C-5979.

ENGINEER EXECUTIVE. Twenty years railway, light and power experience public utilities. Eight years Mexico, Cuba, Brazil. Record successful management sales Eastern Cuba for large importers. Working knowledge French, speaks Spanish, Portuguese. Prefers construction or reconstruction electric properties in Latin countries. Available. B-5729.

EXPERIENCED ELECTRICAL ENGINEER, 28, married. Four years' experience, now employed. Desires connection where executive ability is required. Capable of commanding a salary of $5000 a year. Will move to new location. Available any time. Correspondence invited. C-7902.

GRADUATE ELECTRICAL ENGINEER, Georgia Tech. 1930, Cooperative Plan. Worked alternate months, five years, rebuilding transformers, switches, lightning arresters, substation, maintenance, primary and customers' electric furnaces, rectifiers, motors, etc. Checking and mapping distribution systems, work orders. Single, excellent physical condition. Desires position public utilities. Location, immaterial. C-7847.

GRADUATE ELECTRICAL ENGINEER, two years power house and substation electrical design, four years industrial plant electrical engineer. Recently manufacturers' representative for electrical and mechanical equipment. Broad theoretical and practical experience. Good personality. Desire connection in contact, sales, or application engineering work requiring high degree of technical knowledge. Location, immaterial. C-2745.

ELECTRICAL ENGINEER, 43, for responsible work in public utilities, management, engineering, construction, and investigations. Electric, water, gas and ice companies. Has had ten years in South America. C-5846.

GRADUATE ELECTRICAL ENGINEER, 37, married. Four years' experience with design, construction, maintenance of distribution systems and transformer substations; eight years electrical engineer for coal company; two years efficiency and research engineer; two years electrical designing engineer for cement mills. Desires connection with public utility coal company or industrial concern. C-5277.

ELECTRICAL ENGINEER, 28, B. S. degree. Two years' shop experience on manufacturing of electrical apparatus. Also, two years' experience in design and production. Desires position with concern where there are opportunities for advancement. C-2882.

ELECTRICAL ENGINEER, 30, unmarried. Speaks French and Portuguese. Familiar with design and construction of transmission and distribution lines, and operation of steam and hydro plants. Rural electrification, valuation, and appraisal and management of small lighting companies. C-7403.

SALES ENGINEER. Electrical and mechanical training at Worcester Polytechnic Institute. One year manufacturing, five years, sales and executive experience. Would like opportunity to develop sales or assist in sales management. C-5431.

RESEARCH ENGINEER, chief engineer, electrical engineer, with E. E. and M. S. degrees, desires position where experience in railway and traffic signaling, general research and electrical design, world wide patents, prominent licencees, teaching, and technical writing would be useful. C-7828.

PHYSICIST with doctor's degree, middle-aged, with experience in both teaching and industry. Training and experience chiefly along electrical lines, including development work in radio, electric and magnetic measurements, and alternating current theory and practise. Present position combines executive duties, general responsibility for laboratory equipment and research activites. C-7900.

MEMBERSHIP—Applications, Elections, Transfers, Etc.

APPLICATIONS FOR ELECTION

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated, the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a grade higher than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before September 30, 1930.

Aarnes, O. H., Central Hudson Gas & Electric Corp., Poughkeepsie, N. Y.
Bartlett, O. W., Fraser-Brace Engineering Co. Ltd., Montreal, Que., Can.
Baugh, C. E., (Member), Pacific Gas & Electric Co., San Francisco, Calif.
Borgman, T. J., Southern Bell Tel. & Tel. Co., Louisville, Ky.
Brainard, D. E., General Electric Co., Schenectady, N. Y.
Brown, W. A., (Member), 205 East 42nd St., New York, N. Y.
Campbell, B. F., Pennsylvania Railroad Co., Philadelphia, Pa.
Carnahan, R. B., Paramount Fire Alarm Engineering Co., Cleveland, Ohio
Dawe, P. H., (Member), Sterling Appraisal Co., Ltd., Toronto, Ont., Can.
England, W. L., Messrs. Ferranti Electric Ltd., Toronto, Ont., Can.
Fisher, E. H., Coast Counties Gas & Electric Co., Santa Cruz, Calif.
Hansen, C. J. M., (Member), Gibbs & Hill, New York, N. Y.
Holton, J. L., New York & Queens Elec. Lt. & Pr. Co., Flushing, N. Y.
House, H. E., Aluminum Co. of America, Calderwood, Tenn.
Hunt, C. L., B. C. Electric Railway Co., Burrard Inlet, B. C., Can.
Jester, M. D., Central Power & Light Co., San Antonio, Texas
Judson, L. H., Cincinnati & Suburban Bell Tel. Co., Cincinnati, Ohio
Kaminchan, G. S., 1200 Taylor St., San Francisco, Calif.
Ketcham, D. C., (Fellow), Spooner & Merrill, Inc., Chicago, Ill.
Matsuo, T., Imperial Japanese Navy, New York, N. Y.
Morris, R. L. (Member), New York Edison Co., New York, N. Y.

Quinlan, R. E., Massachusetts Institute of Technology, Cambridge, Mass.
Rapp, C. P., Mexican Tel. & Tel. Co., Mexico, D. F., Mex.
Smith, E. K., Gulf Refining Co., Philadelphia, Pa.
Tibbetts, F. H., (Member), 1320 Alaska Commercial Bldg., San Francisco, Calif.
Uline, W. A., Northern Electric Co., Montreal, Que., Can.
Vitzius, R., Bogue Electric Co., Hoboken, N. J.
Zimmerman, E. E., Edgewood Arsenal, Edgewood, Md.
Total 29

Foreign

Allcock, H. J., (Member), Callender's Cable & Construction Co., Ltd., Belvedere, Kent, England
Burt, B. M., (Member), Harland Engineering Co., Ltd., London, Eng.
Chow, Y., (Member), Chekiang Provincial Tel. Administration, Antwerp, Belgium
Critchley, V. F., (Member), Public Works Department, Lahore, Punjab, India
Eberman, J. W., Anglo-Chilean Consolidated Nitrate Corp., Tocopilla, Chile, So. America
Finkel, J., Sao Paulo Tramway Light & Power Co., Sao Paulo, Brazil, So. America
Jackson, J. B., Perak River Hydro-Electric Co., Ltd., Perak, Federated Malay States
Karanam, A., Government of Madras, Rajahmundry, S. India
Lienhard, E., Anglo-Chilean Consolidated Nitrate Corp., Tocopilla, Chile, So. America
Mackinnon, W. J., Anglo-Chilean Nitrate Corp., Tocopilla, Chile, So. America
Subramanian, P., Messrs. Moylan & Co., Coimbatore, Deccan, India
Total 11

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Clemson Agri. College, Clemson College, S. C.	(4)	C. E. Jarrard	G. A. Douglass	S. R. Rhodes
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Colorado, University of, Boulder, Colo.	(6)	R. Partington	John Buffo	W. C. DuVall
Cooper Union, New York, N. Y.	(3)	H. Reuter	H. Grissler	A. J. B. Fairburn

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Georgia School of Tech., Atlanta, Ga.	(4)	B. L. Palmer	H. A. List	T. W. Fitzgerald
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Iowa State College, Ames, Iowa	(5)	George A. Estel	A. W. Chewning	F. A. Fish
Iowa, State University of, Iowa City, Iowa	(5)	T. F. Taylor	L. N. Miller	E. B. Kurtz
Kansas State College, Manhattan, Kansas	(7)	H. E. Trekell	E. W. Bennett	R. G. Kloeffler
Kansas, Univ. of, Lawrence, Kansas	(7)	Harry Immich		
Kentucky, Univ. of, Lexington, Ky.	(4)	S. M. Worthington		W. E. Freeman
Lafayette College, Easton, Pa.	(2)		Wm. F. Titus	Morland King
Lehigh University, Bethlehem, Pa.	(2)	P. W. Seal	L. R. Wanner	J. L. Beaver
Lewis Institute, Chicago, Ill.	(5)	G. W. Malstrom	E. R. Borden	F. A. Rogers
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Louisville, Univ. of, Louisville, Ky.	(4)	John G. Lips	Wm. E. Bailey	S. T. Fife
Maine, University of, Orono, Maine	(1)	A. E. Crockett	H. R. Mayers	W. E. Barrows, Jr.
Marquette University, 1200 Michigan St., Milwaukee, Wis.	(5)	David Becker	Edward Halback	Edward Kane
Massachusetts Institute of Technology, Cambridge, Mass.	(1)	R. H. Swingle	C. M. Twelves, Jr.	W. H. Timbie
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North Carolina, Univ. of, Chapel Hill, N. C.	(4)		Charles Hayes	J. E. Lear
North Dakota Agricultural College, State College Station, Fargo, N. D.	(6)	R. Stockstad	R. Carlson	H. S. Rush
North Dakota, Univ. of, University Station, Grand Forks, N. D.	(6)	C. J. Breitwieser	R. C. McConnell	H. F. Rice
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Purdue University, Lafayette, Indiana	(5)	A. Simon	C. B. Bruse	A. N. Topping
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Rhode Island State College, Kingston, R. I.	(1)			Wm. Anderson
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South Dakota, Univ. of, Vermillion, S. D.	(6)	Myron Cole	Carl Bauman	B. B. Brackett
Southern California, Univ. of, Los Angeles, Calif.	(8)	Rodney Lewis	J. G. Ellis	Wm. G. Angermann
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West Virginia University, Morgantown, W. Va.	(2)	C. E. Moyers	G. H. Hollis	A. H. Forman
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NEW CATALOGUES AND OTHER PUBLICATIONS

Mailed to interested readers by issuing companies

Suspension Insulators.—Bulletin, 20 pp. Describes Locke suspension insulators for high voltage transmission lines. Locke Insulator Corporation, So. Charles & Cromwell Streets, Baltimore, Md.

Mine Locomotives.—Bulletin 1873, 28 pp. Describes Baldwin-Westinghouse mine and industrial locomotives. Westinghouse Electric & Mfg. Company, East Pittsburgh.

Arc Welding Structural Steel.—Bulletin GEA-1161, 24 pp. Illustrates the use of arc welding in steel structure design, fabrication and erection. General Electric Co., Schenectady, N. Y.

Direct-Current Volt-Ammeters.—Supplement to Bulletin 100, 4 pp. Describes type "PD" pocket portable volt-ammeter and type "HTD" headlight tester. Roller-Smith Company, 12 Park Place, New York.

Measuring Instruments.—Catalog F, 120 pp. Describes the General Radio line of instruments for electrical measurements at communication frequencies. General Radio Company, 30 State Street, Cambridge A, Mass.

Resistance Thermometers.—Catalog 80, 28 pp. Treats in detail of Leeds & Northrup resistance thermometers for recording, controlling and indicating temperature. Leeds & Northrup Company, 4901 Stenton Avenue, Philadelphia.

Oil Electric Locomotives.—Bulletin 1880, 60 pp. Describes applications, operation and construction of oil electric traction apparatus, including illustrations and diagrams of many locomotives and cars. Westinghouse Electric & Mfg. Company, East Pittsburgh.

Graphite Resistances.—Bulletin 11.1, 4 pp. Describes "Aquadag" colloidal graphite, used to form tenacious graphite coatings on paper, fibre, glass, etc., and extensively utilized in the manufacture of certain types of electrical resistances. Acheson Oildag Company, 654 Madison Avenue, New York.

Photoelectric Cells.—Booklet, 34 pp. "The Arcturus Photolytic Cell." According to the booklet, in addition to describing the "Photolytic Cell," its aim is to present to experimental pioneers a fundamental working knowledge of photoelectricity. Arcturus Radio Tube Company, 260 Sherman Avenue, Newark N. J.

Cutouts. Bulletin 508, 12 pp. Describes a new line of fusing equipment. These cutouts possess the same characteristics as the wet process porcelain housed Matthews fuswitches, but differ in that the cutouts have the cartridge mounted on the door and they do not have the double vacuum type fuse cartridge. W. N. Matthews Corporation, 3722 Forest Park Blvd., St. Louis, Mo.

Waste Heat Boilers.—Bulletin WB-30-2, 16 pp. The boilers described are of an entirely different character from those used in the past, consisting of heating elements built of seamless steel tubes covered with cast iron extended surface, reamed to size and shrunk on the heating tubes. The first installations were made in connection with the exhaust gases from Diesel engines. It has been found that in this service the boilers act as excellent mufflers. Also, when operating with waste heat gases not exceeding 800° F. it is not necessary to by-pass the boilers for protection, even when dry. The catalog shows several designs, installations and details of construction of interest to those having waste gases at temperatures above 500 deg. Foster Wheeler Corporation, 165 Broadway, New York.

NOTES OF THE INDUSTRY

Pacific Electric Opens Branch Office.—The Pacific Electric Manufacturing Corporation has opened a new factory office at 89 Broad Street, Boston, in charge of G. A. Wright.

Ohio Brass Appoints Lindsay Ellms.—According to an announcement of the Ohio Brass Company, Mansfield, O., Lindsay Ellms, formerly of the Condit Electrical Manufacturing Corporation has joined the Ohio Brass Company, with headquarters in Boston.

The Okonite Company Appoints T. T. Kennedy.—According to an announcement of the Okonite Company, manufacturers of insulated wires and cables, Theodore T. Kennedy has been appointed district manager of its Los Angeles office. Mr. Kennedy joined the company in 1924 at its factory in Passaic, N. J. He was later promoted to the district office of the Okonite Company in San Francisco where he has been sales representative in the Pacific Coast territory.

Kearney Corp. Acquires Thanders Elec. Co.—The James R. Kearney Corporation, manufacturers of overhead and underground electrical specialties, St. Louis, announces the purchase of the Thanders Electric Company, a St. Louis concern, makers of T-H Equipment for central stations, line constructions, railway systems, industrials and complete substations.

Electrad, Inc., Expands Export Department.—The progress of Electrad, Inc. in developing foreign markets for its line of resistors and voltage controls as well as amplifiers and sound equipment, has necessitated the enlargement of its export department, according to a statement by Arthur Moss, president of the company. Xavier de Nice has been appointed export manager. Mr. de Nice was formerly merchandising counsel for the American Exporter and for ten years was export manager for the American Chain Company and associated companies.

George W. W. Cornman Retires from Brown Instrument Company.—The Brown Instrument Company, Philadelphia, announces that George W. W. Cornman, treasurer, and manager of the service department, has retired from the business. Mr. Cornman was associated with the instrument business for thirty-five years, formerly being secretary and treasurer of the Keystone Electrical Instrument Company. When that organization was absorbed by the Brown Instrument Company he became treasurer and director of the present organization.

Transportation of Oil by Electricity.—Eighteen 800 hp. synchronous motors, the largest electric motors ever applied to pipe line pumping, and two 450 hp. synchronous motors will drive the centrifugal pumps moving the oil in the new pipe line of the Texas Empire Pipe Line Company. These pumps will deliver, through a 10″ pipe, 30,000 barrels of oil per day from Chetopa and Sand Springs, Oklahoma, through Cole Camp and Centralia, Missouri, to the refineries at Bayless and Broadwell, Illinois. The motors and complete control equipment for them are supplied by the Westinghouse Electric & Mfg. Company.

Full Lightning Tests for Commercial Transformers.—Full lightning tests have been applied to commercial transformers for the first time according to the General Electric Company. The high voltage laboratory at Pittsfield, Mass., has repeatedly subjected transformers of the new non-resonating type to 3,000,000-volt lightning waves. The transformers, built at Pittsfield for use on the Fifteen Mile Falls 220,000-volt transmission line of the New England Power Company, are rated 13,000 kv-a. each. The lightning tests, conducted under the direction of F. W. Peek, Jr., on August 8 and 12, were made immediately after the commercial tests of the units were completed.

The 3,000,000-volt lightning waves used in the tests were conducted from the high voltage laboratory over a short line to the testing department and repeatedly applied to the transformers. The transmission line insulation arrangement was made to compare with operating conditions, with 15 shielded units on the main line and 14 units at the transformer. The lightning waves were of a type to produce the severest stresses, and covered a range of time varying from one-half microsecond front to 80 microseconds tail. It was found impossible to break down the transformers in the tests, and a repetition of the commercial tests showed no damage.